6SE50 MAY 1995

SERIES 50®
Service Manual

Detroit Diesel® Series 50® Engines

DETROIT DIESEL CORPORATION ®

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NOTE:
Additional copies of this service manual may be purchased from Detroit Diesel Corporation Distributors. See your yellow pages — under Engines, Diesel.

Printed in U.S.A.

CALIFORNIA
Proposition 65 Warning

Diesel Engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects and other reproductive harm.

CAUTION:

To reduce the chance of personal injury and/or property damage, the following instructions must be carefully observed.

Proper service and repair are important to the safety of the service technician and the safe, reliable operation of the engine. If part replacement is necessary, the part must be replaced with one of the same part number or with an equivalent part number. Do not use a replacement part of lesser quality.

The service procedures recommended and described in this manual are effective methods of performing repair. Some of these procedures require the use of specially designed tools.

Accordingly, anyone who intends to use a replacement part, procedure or tool which is not recommended, must first determine that neither personal safety nor the safe operation of the engine will be jeopardized by the replacement part, procedure or tool selected.

It is important to note that this manual contains various "Cautions" and "Notices" that must be carefully observed in order to reduce the risk of personal injury during repair or the possibility that improper repair may damage the engine or render it unsafe. It is also important to understand that these "Cautions" and "Notices" are not exhaustive, because it is impossible to warn personnel of the possible hazardous consequences that might result from failure to follow these instructions.

ABSTRACT

This manual provides instruction for servicing on-highway, construction and industrial, and generator set applications of the Detroit Diesel Series 50 Engine.

Specifically a basic overview of each major component and system along with recommendations for removal, cleaning, inspection, criteria for repair or replacement, repair and installation are contained in this manual. Troubleshooting concerns of Detroit Diesel Series 50 Engines are contained in the *Series 50 Engine Troubleshooting Manual*, 6SE494.

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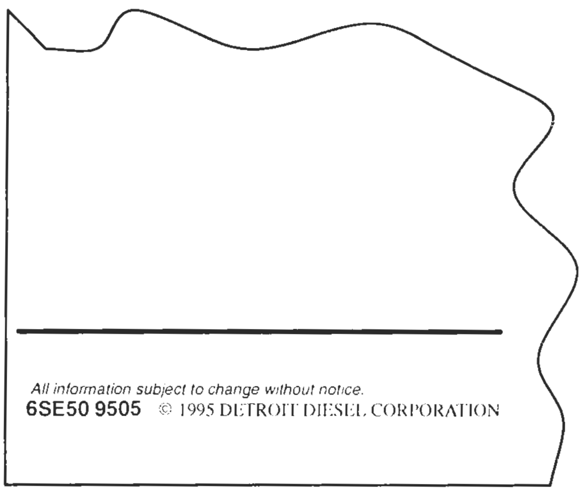
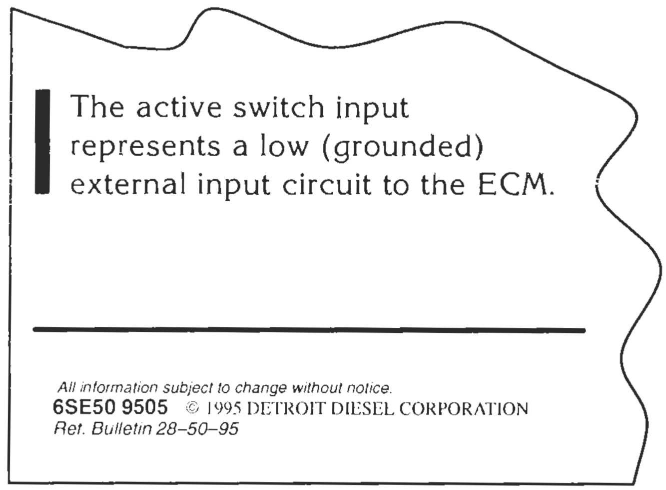
REVISION NOTIFICATION

Revisions to this manual will be sent marked with a revision bar (see Example 2). Sections containing revisions will have a third line in the page footer (compare Examples 1 and 2).



Example 1– Unchanged Pages



Example 2– Changed Pages

GENERAL INFORMATION

SCOPE AND USE OF THIS MANUAL

This manual contains complete instructions on operation, adjustment (tune–up), preventive maintenance, and repair (including complete overhaul) for the basic Series 50 Inline Diesel Engines. This manual was written primarily for persons servicing and overhauling the engine. In addition, this manual contains all of the instructions essential to the operators and users. Basic maintenance and overhaul procedures are common to all Series 50 Engines, and apply to all engine models.

This manual is divided into numbered sections. The first section covers the engine (less major assemblies). The following sections cover a complete system such as the fuel system, lubrication system, or air system. Each section is divided into subsections which contain complete maintenance and operating instructions for a specific engine sub–assembly. Each section begins with a table of contents. Pages and illustrations are numbered consecutively within each section.

Information can be located by using the table of contents at the front of the manual or the table of contents at the beginning of each section. Information on specific sub–assemblies or accessories within the major section is listed immediately following the section title.

SERVICE PARTS AVAILABILITY

Service parts are available throughout the world. A complete list of all Detroit Diesel Corporation (DDC) distributors and dealers is available in the *Detroit Diesel Corporation World Wide Parts and Service Directory*, 6SE280. This publication can be ordered from any authorized DDC distributor. The dealer must have the engine identification and model number (located on the engine block directly beneath the intake manifold) to fill a parts order.

CLEARANCE OF NEW PARTS AND WEAR LIMITS

New parts clearances apply only when all new parts are used at the point where the various specifications apply. This also applies to references within the text of the manual. The column entitled Limits must be qualified by the judgement of personnel responsible for installing new parts. For additional information, refer to the section entitled "Inspection" within this section. Refer to section 1.A, "Specifications, New Clearances, and Wear Limits" under "Specifications", for a listing of clearances of new parts and wear limits on used parts.

THE FOUR–CYCLE PRINCIPLE

The diesel engine is an internal combustion engine, in which the energy of burning fuel is converted into work in the cylinder of the engine. In the diesel engine, air alone is compressed in the cylinder, raising its temperature significantly. After the air has been compressed, a charge of fuel is sprayed into the cylinder and ignition is accomplished by the heat of compression. The four piston strokes of the cycle occur in the following order: intake, compression, power and exhaust. See Figure 1.

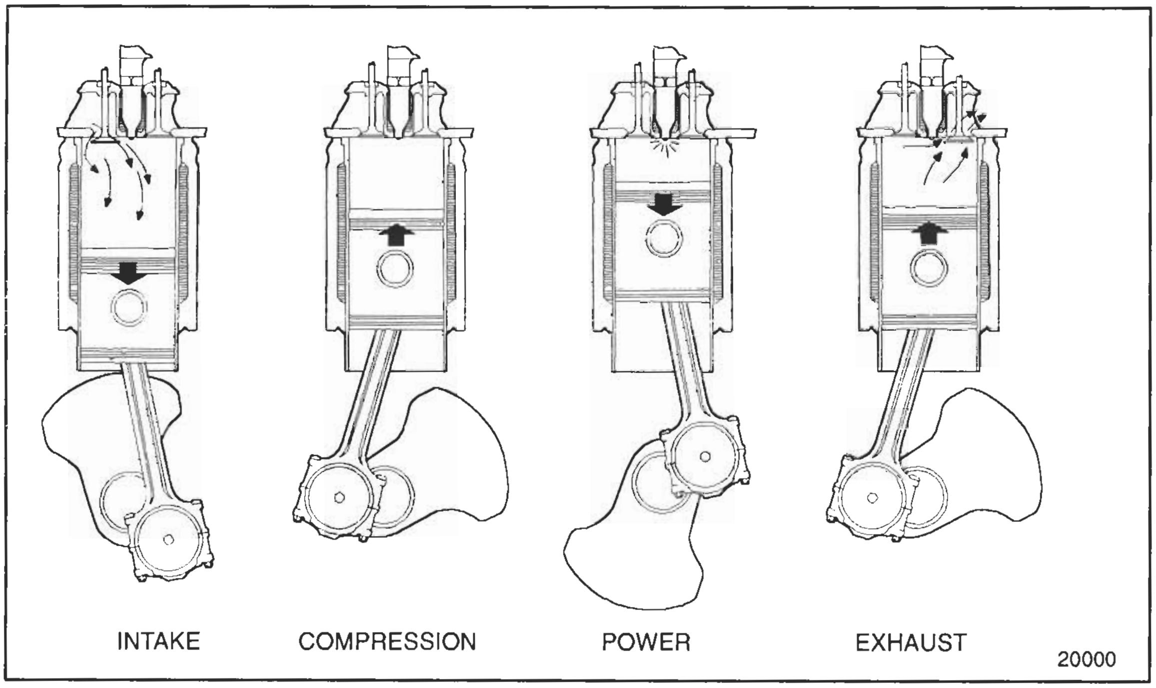


Figure 1 The Four Stroke Cycle

Intake Stroke

During the intake stroke, the piston travels downward, the intake valves are open, and the exhaust valves are closed. The downstroke of the piston facilitates air from the intake manifold to enter the cylinder through the open intake valves. The turbocharger, by increasing the air pressure in the engine intake manifold, assures a full charge of air is available for the cylinder.

The intake charge consists of air only with no fuel mixture.

Compression Stroke

At the end of the intake stroke, the intake valves close and the piston starts upward on the compression stroke. The exhaust valves remain closed.

At the end of the compression stroke, the air in the combustion chamber has been compressed by the piston to occupy a space about one-fifteenth as great in volume as it occupied at the beginning of the stroke. Thus, the compression ratio is 15:1.

Compressing the air into a small space causes the temperature of that air to rise. Near the end of the compression stroke, the pressure of the air above the piston is approximately 3445 to 4134 kPa (500 to 600 lb/in.^{2}) and the temperature of that air is approximately 538°C (1000°F). During the last part of the compression stroke and the early part of the power stroke, a small metered charge of fuel is injected into the combustion chamber.

Almost immediately after the fuel charge is injected into the combustion chamber, the fuel is ignited by the hot air and starts to burn, beginning the power stroke.

Power Stroke

During the power stroke, the piston travels downward and all intake and exhaust valves are closed.

As the fuel is added and burns, the gases get hotter, the pressure increases, pushing the piston downward and adding to crankshaft rotation.

Exhaust Stroke

During the exhaust stroke, the intake valves are closed; the exhaust valves are open, and the piston is on its upstroke.

The burned gases are forced out of the combustion chamber through the open exhaust valve port by the upward travel of the piston.

From the preceding description, it is apparent that the proper operation of the engine depends upon the two separate functions: first, compression for ignition, and second, that fuel be measured and injected into the compressed air in the cylinder in the proper quantity and at the proper time.

GENERAL DESCRIPTION

The Series 50 Diesel Engine described in this manual is a four-stroke cycle, high speed, diesel engine.

It uses an inline cast iron block and has a cast iron cylinder head that contains a single overhead camshaft. The camshaft actuates all the valves (two intake, two exhaust per cylinder), and operates the fuel injectors. The vertically aligned gear train, located at the front end of the engine in a gear case, contains drive gears for the lubricating oil pump, crankshaft, camshaft, air compressor drive, fuel pump drive, water pump and alternator accessory drives.

Each current engine is equipped with dual full flow oil filters, a bypass oil filter, an oil cooler, two fuel oil filters, a turbocharger and an electronic engine control system.

Full pressure lubrication is supplied to all main, connecting and camshaft bearings, and to other moving parts. A gear-type pump draws oil from the oil pan through a screen and delivers it to the oil filters. From the filter, a small portion of the oil is delivered directly to the turbocharger by an external oil line. The remainder of the oil flows to the oil cooler, or bypasses the cooler, and then enters a longitudinal oil gallery in the cylinder block where the supply divides. Part of the oil goes to the cylinder head where it feeds the camshaft bearings and rocker assemblies; part of the oil goes to the main bearings and connecting rod bearings via the drilled oil passages in the crankshaft. The remainder of the oil feeds the balance support where it lubricates the balance shaft bearings and is regulated. Drilled passages in the connecting rod feed oil to the piston pin and the inner surface of the piston crown.

Coolant is circulated through the engine by a centrifugal-type water pump. The cooling system, including the radiator, is a closed system. Heat is removed from the coolant by the radiator. Control of the engine temperature is accomplished by thermostats that regulate the flow of the coolant within the cooling system.

Fuel is drawn from the supply tank through the primary fuel filter by a gear–type fuel pump. From there, the fuel is forced through the secondary fuel filter and into the fuel inlet in the cylinder head and to the injectors. Excess fuel is returned, through a restricted fitting, to the supply tank through the outlet connecting line. Since the fuel is constantly circulating through the injectors, it serves to cool the injectors and to carry off any air in the fuel system.

Air is supplied by the turbocharger to the intake manifold and into the engine cylinders after passing through an air–to–air charge air cooler mounted ahead of the cooling system radiator. The charge air cooler cools the pressurized intake air charge coming from the turbocharger before it enters the intake manifold.

Engine starting may be provided by an electric or air starting motor energized by a storage battery or air pressure storage system. A battery charging alternator, with a suitable voltage regulator, serves to keep the battery charged.

The Series 50 Diesel Engine was designed to be electronically controlled. The Detroit Diesel Electronic Control (DDEC) system has evolved with the product.

DDEC II

DDEC II controls the timing and amount of fuel injected into each cylinder. The system monitors several engine sensors that send electrical signals to the main ECM. See Figure 2. Unlike DDEC I, the DDEC II ECM uses this information to actuate the Electronic Unit Injector (EUI) solenoids. The ECM also has the ability to limit or shut down the engine completely (depending on option selection) in the case of damaging engine conditions, such as low oil pressure, low coolant level, or high oil temperature.

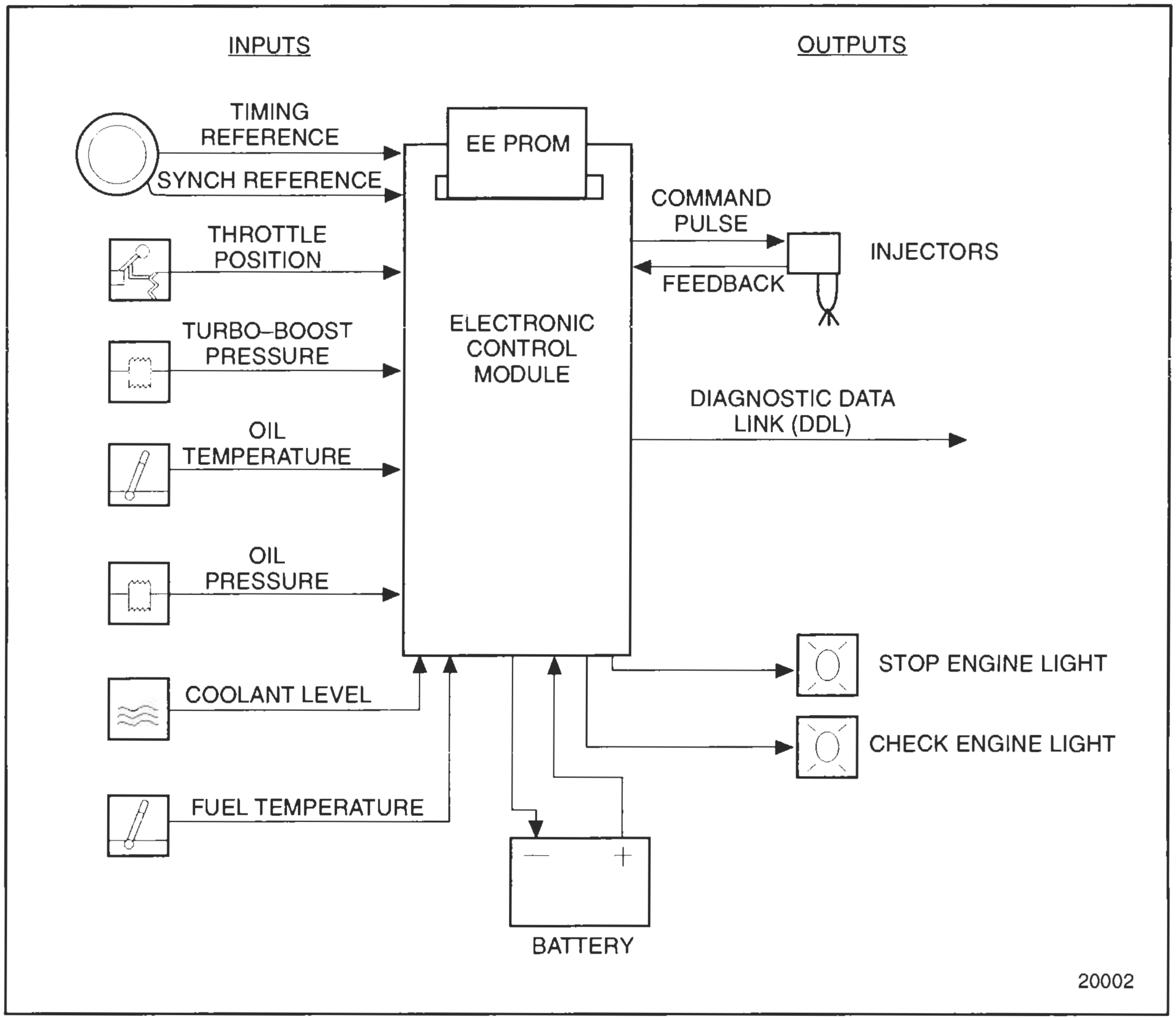


Figure 2 **Schematic Diagram of DDEC II**

DDEC III

The DDEC III ECM receives electronic inputs from sensors on the engine and vehicle, and uses the information to control engine operation. It computes fuel timing and fuel quantity based upon predetermined calibration tables in its memory.

Fuel is delivered to the cylinders by the EUI solenoids, which are cam–driven to provide the mechanical input for pressurization of the fuel. The ECM controls solenoid operated valves in the EUIs to provide precise fuel delivery. See Figure 3.

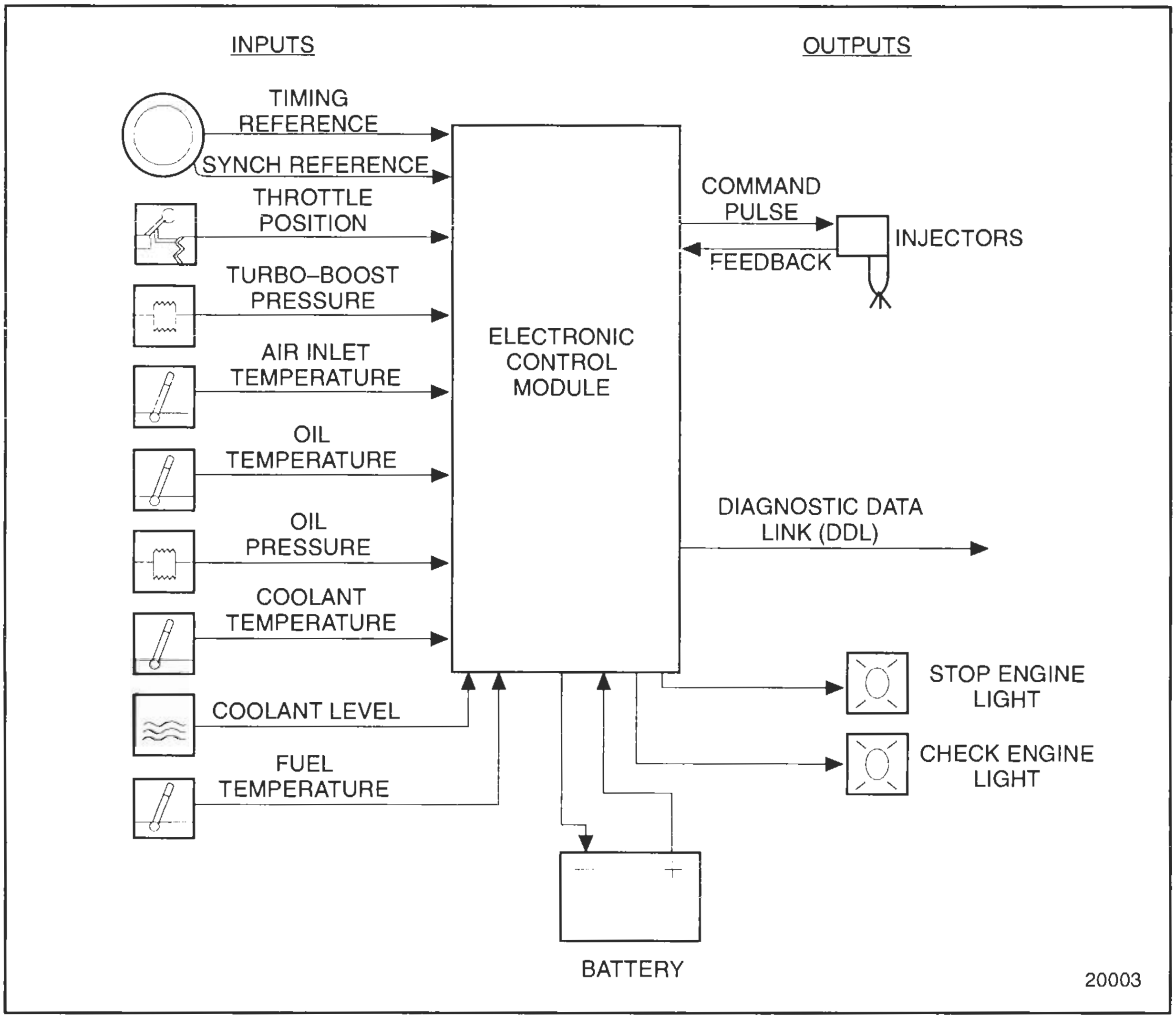


Figure 3 Schematic Diagram of DDEC III

Portable equipment facilitates access to DDEC III's diagnostic capabilities. The Diagnostic Data Reader (DDR) requests and receives engine data and diagnostic codes. This equipment provides many unique capabilities including cylinder cutout, parameter vs. engine speed (or time), printer output, and data snapshot. The DDR also provides limited programming capability.

GENERAL SPECIFICATIONS

The general specifications for the Series 50 Engine are listed in Table 1. See Figure 4 for the cylinder designation and firing order.

General Specifications	Engine Family
Total Displacement (L)	8.5
Total Displacement (in.^{3})	518
Type	Four–cycle
Number of Cylinders	4
Bore (in.)	5.12
Bore (mm)	130
Stroke (in.)	6.30
Stroke (mm)	160
Compression Ratio	15.0:1
Number of Main Bearings	5

Table 1 General Specifications for the Series 50 Engine

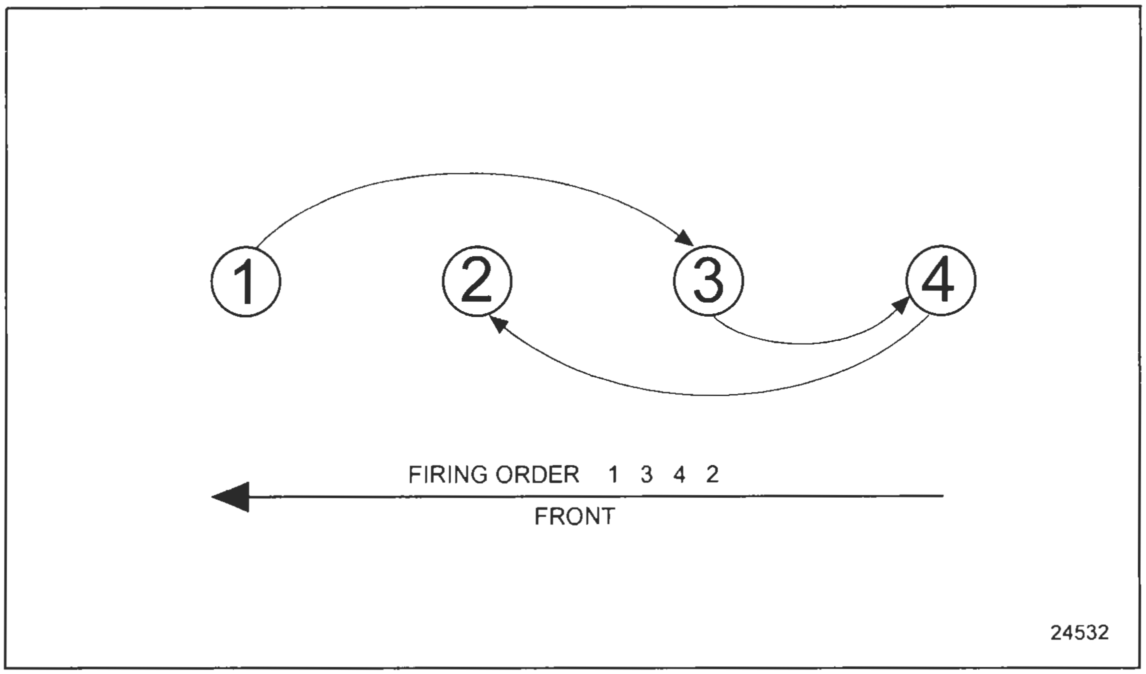


Figure 4 Cylinder Designation and Firing Order

ENGINE MODEL, SERIAL NUMBER AND OPTION LABEL

The engine serial and model numbers are stamped on the cylinder block. See Figure 5. A guide to the meaning of the serial number digits is listed in Table 2.

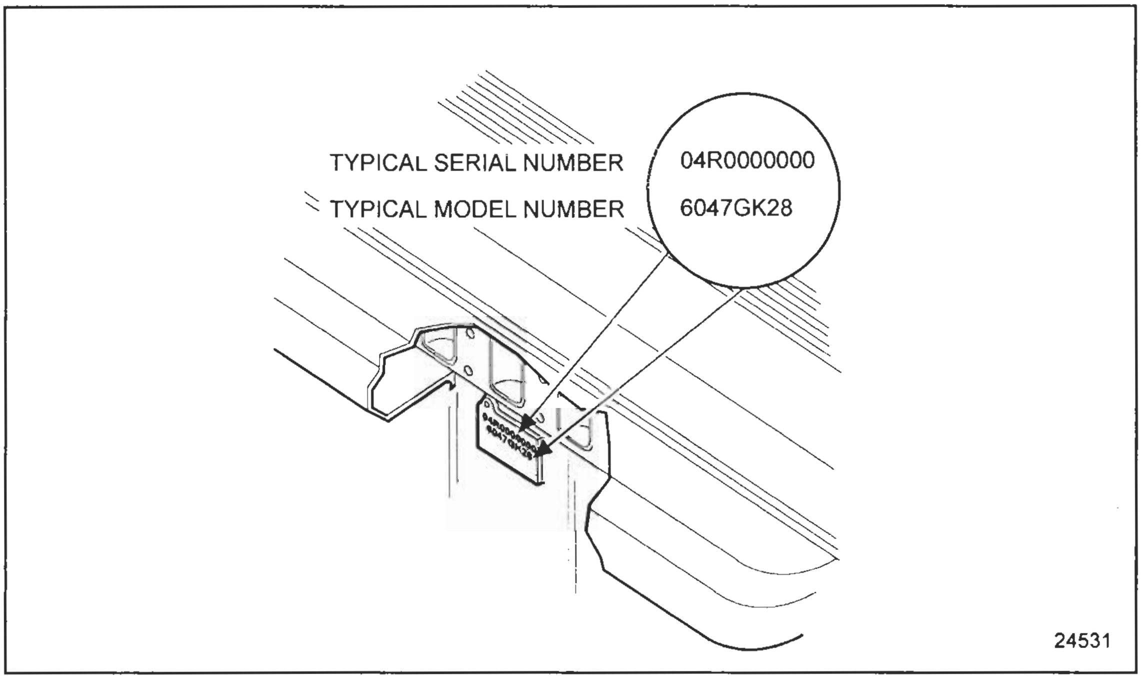


Figure 5 Location of Engine Serial and Model Number on Block

Digit	Value	Meaning
1	6	Series 50 Engine
2 & 3	04	Four Cylinders
4	7	Automotive Application
5	G	8.5 L Displacement
6	U	DDEC II Engine Control
6	K	DDEC III Engine Control
7 & 8	28	"T" Drive
7 & 8	26	"V" Drive

Table 2 Model Number Description for Series 50

Option labels attached to the valve rocker cover contain the engine serial and model numbers and list any optional equipment used on the engine. See Figure 6.

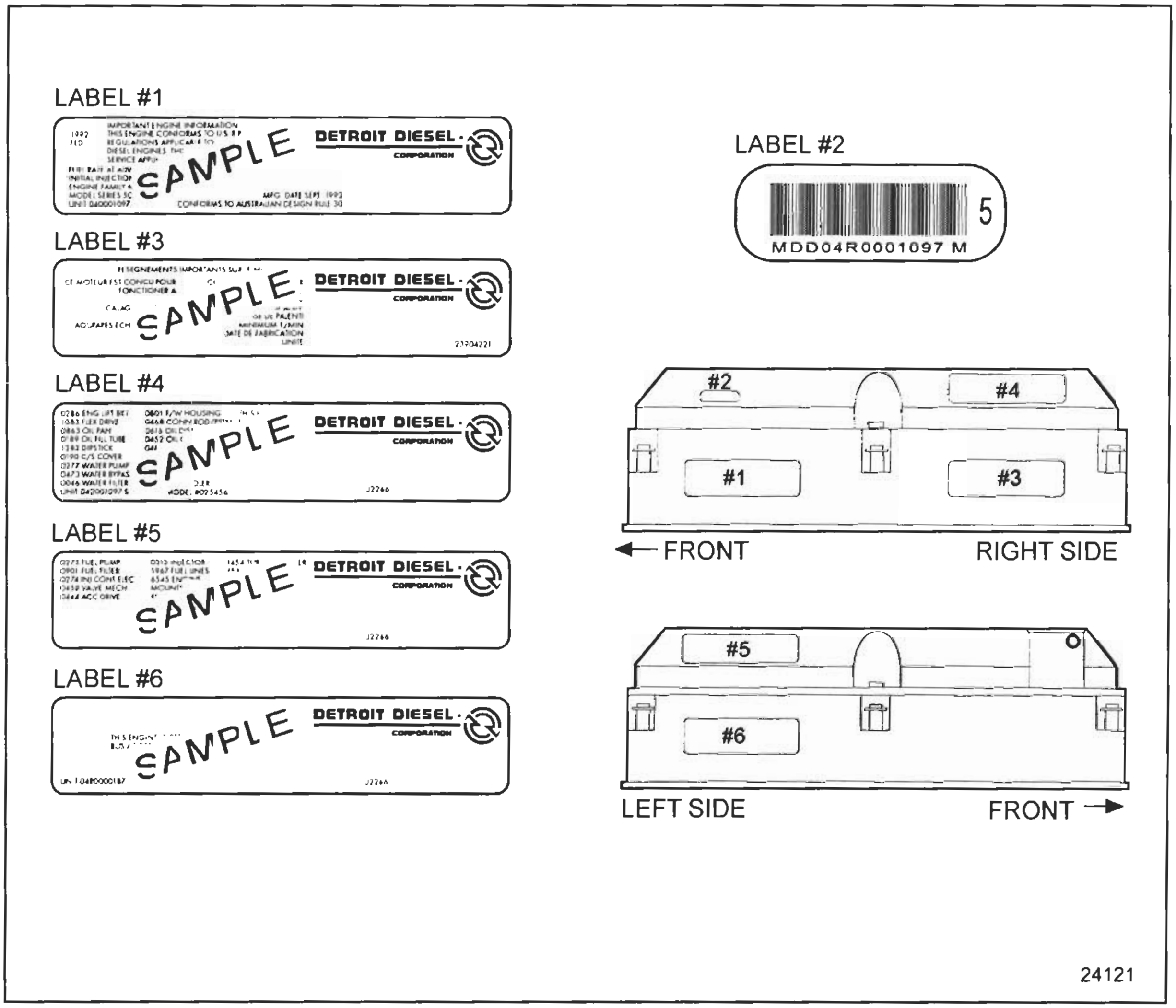


Figure 6 Rocker Cover with Option Label

With any order for parts, the engine model number with serial number should be given. In addition, if a type number is shown on the option plate covering the equipment required, this number should also be included on the parts order.

All groups or parts used on a unit are standard for the engine model unless otherwise listed on the option plate.

REPLACING AND REPAIRING

In many cases, a serviceman is justified in replacing parts with new material rather than attempting repair. However, there are times when a slight amount of reworking or reconditioning may save a customer considerable added expense. Exchange assemblies such as injectors, fuel pumps, water pumps and turbochargers are desirable service items.

Various factors such as the type of operation of the engine, hours in service and the next overhaul period must be considered when determining whether new parts are installed or used parts are reconditioned to provide trouble–free operation.

For convenience and logical order in disassembly and assembly, the various subassemblies and other related parts mounted on the cylinder block will be treated as separate items in the various sections of the manual.

DISASSEMBLY

A service person can be severely injured if caught in pulleys, belts or the fan of an engine that is accidentally started. To avoid such a misfortune, take the following precautions before starting to work on an engine.

CAUTION:

Disconnect the battery or batteries from the starting system by removing one or both of the battery cables from each system battery. With the electrical circuit disrupted, accidental contact with the starter button will not produce an engine start. In addition, the Electronic Unit Injectors (EUI) will be disabled, preventing any fuel delivery to the injector tips. If the engine is equipped with an air starter, drain the air storage tank and disconnect the air supply to the starter before beginning engine disassembly.

Before any major disassembly, the engine must be drained of lubricating oil, coolant and fuel.

To perform a major overhaul or other extensive repairs, the complete engine assembly, after removal from the engine base and drive mechanism, should be mounted on an engine overhaul stand; then the various subassemblies should be removed from the engine. When only a few items need replacement, it is not always necessary to mount the engine on an overhaul stand.

Parts removed from an individual engine should be kept together so they will be available for inspection and assembly. Those items having machined faces, which might be easily damaged by steel or concrete, should be stored on suitable wooden racks or blocks, or a parts dolly.

CLEANING

Before removing any of the subassemblies from the engine (but after removal of the electrical equipment), the exterior of the engine should be thoroughly cleaned.

NOTICE:
The Series 50 Engine is equipped with various sensors and other electronic components which may be damaged if subjected to the high temperatures in a solvent tank. Do *not* immerse any electrical components in a solvent tank. Care should be taken to ensure that all electronic components are removed from the various engine assemblies before they are immersed in a solvent tank. Refer to section 2.8 for a description of these components.

Then, after each subassembly is removed and disassembled, the individual parts should be cleaned. Thorough cleaning of each part is absolutely necessary before it can be satisfactorily inspected. Various items of equipment needed for general cleaning are listed below.

The cleaning procedure used for all ordinary cast iron parts is the same as the following cylinder block cleaning procedure. Any special cleaning procedures will be mentioned when required.

Remove cylinder liners with the cylinder liner removal tool, J 35791, before putting the block in cleaning or descaling baths, to avoid trapping cleaning agents in block liner seating bores.

After stripping and before removing the cylinder block from the overhaul stand for cleaning and inspection, install the two metric eye bolts, J 35595, into head bolt holes at each end of the cylinder block.

Remove all oil and water gallery and weep hole plugs to allow the cleaning solution to enter the inside of the oil and water passages.

1. Using two metric eye bolts, J 35595 installed in the head bolt holes at opposite ends of the block, and with a suitable lifting device and spreader bar, immerse and agitate the block in a hot bath of a commercial, heavy-duty alkaline solution.
2. Wash the block in hot water or steam clean it to remove the alkaline solution.

3. If the water jackets are heavily scaled, proceed as follows:
   [a] Agitate the block in a bath of inhibited phosphoric acid.
   [b] Allow the block to remain in the acid bath until the bubbling action stops (approximately 30 minutes).
   [c] Lift the block, drain it and re-immerse it in the same acid solution for 10 more minutes. Repeat until all scale is removed from the water jacket area.
   [d] Rinse the block in clear, hot water to remove the acid solution.
   [e] Neutralize the acid that may cling to the casting by immersing the block in an alkaline bath.
   [f] Wash the block in clean water or steam clean it.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

4. Dry the cylinder block with compressed air.
5. Blow out all of the bolt holes and passages with compressed air.

NOTE:
The above cleaning procedure may be used on all ordinary cast iron and steel parts for the engine. Aluminum parts, such as flywheel housing, air intake manifold, oil filter adaptor and the camshaft gear access cover should NOT be cleaned in this manner. Mention will be made of special procedures when necessary.

6. Be certain that all water passages and oil galleries have been thoroughly cleaned. After the cylinder block has been thoroughly cleaned and dried, install weep hole plugs and precoated pipe plugs. Install new cup plugs using a coating of good grade non-hardening sealant such as Loctite 620 or equivalent.

Steam Cleaning

A steam cleaner is a necessary item in a large shop and is most useful for removing heavy accumulations of grease and dirt from the exterior of the engine and its subassemblies.

Solvent Tank Cleaning

A tank of sufficient size to accommodate the largest part that will require cleaning (usually the cylinder block) should be provided and provisions made for heating the cleaning solution to 82–90°C (180–200°F).

Fill the tank with a commercial heavy–duty solvent that is heated to 82–90°C (180–200°F). Lower large parts directly into the tank with a hoist. Place small parts in a wire mesh basket and lower them into the tank. Immerse the parts long enough to loosen all of the grease and dirt.

NOTE:
Aluminum or plastic parts such as the flywheel housing, fuel pump drive, air intake manifold, oil filter adaptor, camshaft gear access cover, oil pan or rocker covers, should not be cleaned in this manner.

Rinsing Bath

Provide another tank of similar size containing hot water for rinsing the parts.

Drying

Parts may be dried with compressed air. The heat from the hot tanks will quite frequently complete drying of the parts without the use of compressed air.

CAUTION:
To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

Rust Preventive

If parts are not to be used immediately after cleaning, dip them in a suitable rust preventive compound. The rust preventive compound should be removed before installing the parts in an engine.

Gasket Eliminator Removal

The gasket eliminator used on numerous mating surface joints in the Series 50 engine results in a very thin film that must be removed from both surfaces prior to reassembly. As many of the surfaces are aluminum and/or dimensionally critical, conventional scraping methods, or the use of emery cloth for removing gasket eliminator is not recommended.

Four–inch, 3M Scotch–Brite Surface Conditioning Discs, used with an electric or air powered hand drill (with a speed of 15,000–18,000 r/min), have proven successful in removing the gasket eliminator without damaging the mating surfaces of engine parts. See Figure 7.

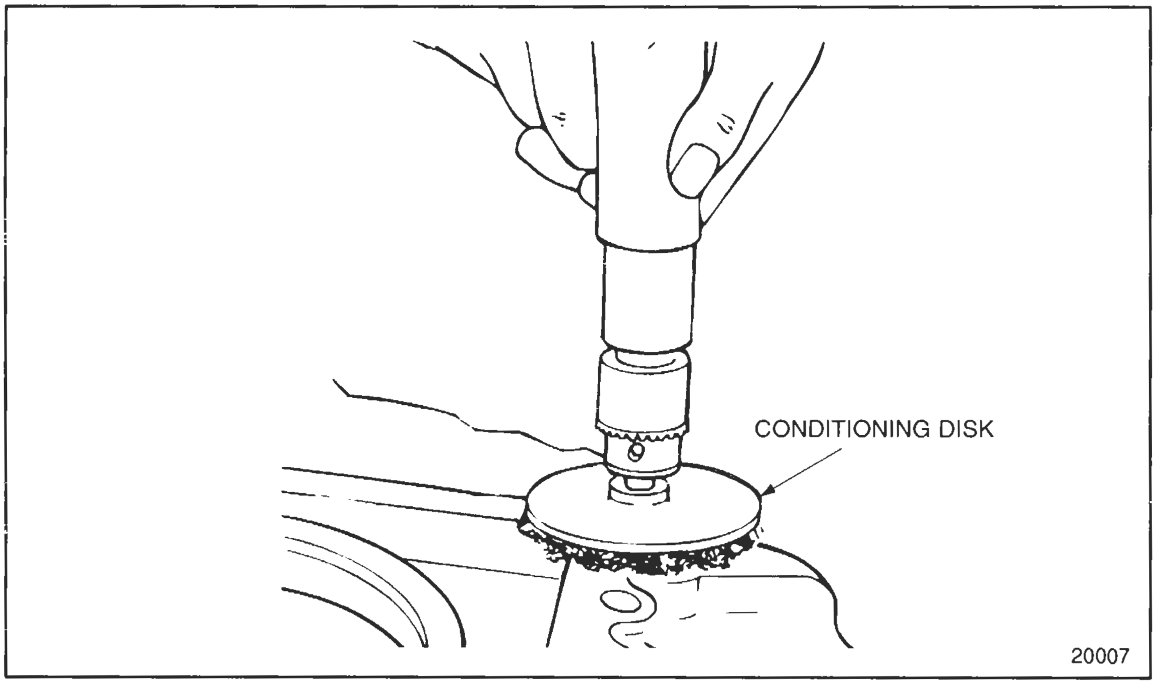


Figure 7 Gasket Eliminator Removal

A coarse pad, J 36571-3, (3M #07450, brown color), is suitable for steel surfaces. A medium pad, J 36571-2 (3M #07451, maroon color), is recommended for aluminum surfaces.

The pads are easily interchangeable using disc holder, J 36571-1 (3M #07492). See Figure 8.

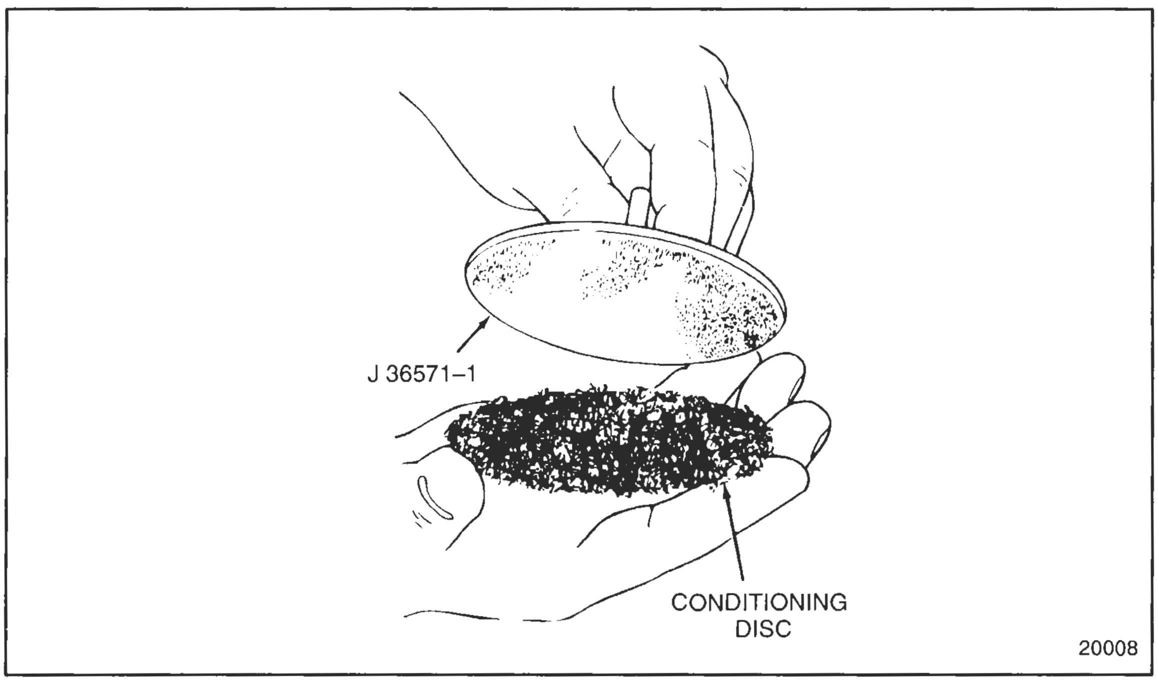


Figure 8 Scotch-Brite Surface Conditioning Disc Installation, J 36571

INSPECTION

The purpose of parts inspection is to determine which parts can be used and which must be replaced. Although the engine overhaul specifications given throughout the text will aid in determining which parts should be replaced, considerable judgment must be exercised by the inspector. The guiding factors in determining the usability of worn parts, that are otherwise in good condition, is the clearance between the mating parts and the rate of wear on each of the parts. If it is determined that the rate of wear will maintain the clearances within the specified maximum allowable until the next overhaul period, the reinstallation of used parts may be justified. Rate of wear of a part is determined by dividing the amount the part has worn by the hours it has operated.

Many service replacement parts are available in various undersize or oversize as well as standard sizes. Also, service kits for reconditioning certain parts and service sets that include all of the parts necessary to complete a particular repair job are available.

A complete discussion of the proper methods of precision measuring and inspection are outside the scope of this manual. However, every shop should be equipped with standard gages, such as dial bore gages, dial indicators, and inside and outside micrometers.

In addition to measuring the used parts after cleaning, the parts should be carefully inspected for cracks, scoring, chipping and other detrimental conditions.

SAFETY PRECAUTIONS

The following safety measures are essential when working on the the Series 50 engine.

> **CAUTION:**
>
> **The exhaust products of an internal combustion engine are toxic and may cause injury or death if inhaled. All engine installations, especially those within closed shelter should be equipped and maintained with an exhaust discharge pipe so that exhaust gases are expelled into the outside air. A closed building or shelter must be adequately vented. A means of providing fresh air into a closed building or shelter is necessary.**

Stands

Safety stands are required in conjunction with hydraulic jacks or hoists. **Do not** rely on either the jack or the hoist to carry the load. When lifting an engine, be sure the lifting device is fastened securely. Be sure the item to be lifted does not exceed the capacity of the lifting device.

Glasses

Select appropriate safety glasses for the job. It is especially important to wear safety glasses when using tools such as hammers, chisels, pullers or punches.

Welding

Wear welding goggles and gloves when welding or using an acetylene torch. Ensure that a metal shield separates the acetylene and oxygen that must be chained to a cart.

> **CAUTION:**
>
> **Do not weld or heat areas near fuel tanks or lines. An explosion could result if heat buildup inside the tank is sufficient. Utilize proper shielding around hydraulic lines.**

Work Place

Organize your work area and keep it clean. Eliminate the possibility of a fall by:

- ❑ Wiping up oil spills
- ❑ Keeping tools and parts off the floor

After servicing or adjusting the engine:

- ❑ Reinstall all safety devices, guards or shields
- ❑ Ensure that all tools and servicing equipment are removed from the engine

Clothing

Safe work clothing fits and is in good repair. Work shoes are sturdy and rough-soled. Bare feet, sandals or sneakers are **not** acceptable foot wear when adjusting and/or servicing an engine.

CAUTION:

To avoid personal injury, do not wear rings, wrist watches, or loose fitting clothing. Any of these items could catch on moving parts and cause serious injury.

Power Tools

Never use defective portable power tools.

CAUTION:

To avoid personal injury, do not use defective portable power tools. Check for frayed cords prior to use. Be sure all electric tools are grounded. Using defective electrical equipment can cause severe injury. Improper use of electrical equipment can result in electrical shock, fire, or explosion under certain conditions which may cause severe injury.

Air

Recommendations regarding the use of air are indicated throughout the manual. Too much air can rupture or in some other way damage a component and create a hazardous situation that can lead to personal injury. Use only approved air blow guns that do not exceed 207 kPa (30 lb/in.^{2}). Be sure to wear safety glasses or goggles. Use proper shielding to protect everyone in the work area.

CAUTION:

To avoid personal injury, do not use defective portable power tools. Check for frayed cords prior to use. Be sure all electric tools are grounded. Using defective electrical equipment can cause severe injury. Improper use of electrical equipment can result in electrical shock, fire, or explosion under certain conditions which may cause severe injury.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

Fuel Lines

Remove fuel lines as an assembly. **Do not** remove fuel lines individually. Avoid getting fuel injection lines mixed up.

Fluids and Pressure

Be extremely careful when dealing with fluids under pressure. Fluids under pressure can have enough force to penetrate the skin. These fluids can infect a minor cut or opening in the skin. If injured by escaping fluid, see a doctor at once. Serious infection or reaction can result without immediate medical treatment.

CAUTION:

To avoid personal do not exceed air pressure recommendations. Too much air can rupture or in some other way damage a component and create a hazardous situation that can lead to personal injury. Use only approved air blow guns that do not exceed 276 kPa (40 lb/in.^{2}). Be sure to wear safety glasses or goggles. Use proper shielding to protect everyone in the work area.

CAUTION:

Do not put your hands in front of fluid under pressure. Fluids under pressure can penetrate skin and clothing and cause injury.

Fuel

Keep the hose and nozzle or the funnel and container in contact with the metal of the fuel tank when refueling.

CAUTION:

To avoid personal injury, use care when dealing with fluids under pressure. Fluids under pressure have enough force to penetrate the skin. These fluids can cause a minor cut or opening in the skin. If injured by escaping fluid, see a doctor immediately. Serious infection or adverse reaction to the fluid can result if not treated immediately.

CAUTION:

Do not over fill the fuel tank; overflow creates a fire hazard.

CAUTION:

To avoid personal injury, do not put your hands in front of fluid under pressure. Fluids under pressure can penetrate skin and clothing and cause injury.

This will avoid the possibility of an electric spark igniting the fuel.

CAUTION:

Do not smoke when refueling. Do not refuel when the engine is hot or running.

Batteries

Electrical storage batteries emit highly flammable hydrogen gas when charging and continue to do so for some time after receiving a steady charge.

CAUTION:
Electrical storage batteries emit highly flammable hydrogen gas when charging. They continue to do so for some time after receiving a steady charge. To avoid personal injury, do not under any circumstances allow an electric spark or open flame near the battery. An explosion may occur.

Always disconnect the battery cable before working on the electrical system.

CAUTION:
To prevent accidental starting which could result in personal injury, disconnect the batteries or disable the air starter (if so equipped).

Disconnect the batteries or disable an air starter when working on the engine (except DDEC) to prevent accidental starting.

Fire

Keep a charged fire extinguisher within reach. Be sure you have the correct type of extinguisher for the situation.

Cleaning Agent

Avoid the use of carbon tetrachloride as a cleaning agent because of the harmful vapors that it releases. Be sure the work area is adequately ventilated. Use protective gloves, goggles or face shield, and apron.

Exercise caution against burns when using oxalic acid to clean the cooling passages of the engine.

Working on a Running Engine

When working on an engine that is running, accidental contact with the hot exhaust manifold can cause severe burns. Remain alert to the location of the rotating fan, pulleys and belts. Avoid making contact across the two terminals of a battery which can result in severe arcing, or battery explosion.

CAUTION:

Avoid personal injury when working on a running engine. Accidental contact with the exhaust manifold can cause severe burns. To avoid personal injury, remain alert to the location of the fan, pulleys, and belts. Avoid making contact across the two terminals of a battery. This can cause arcing or battery explosion.

Start Attempts

Avoid excessive injection of ether into the engine during start attempts. Follow the instructions on the container or by the manufacturer of the starting aid.

Turbocharger Compressor Inlet Shield

A turbocharger compressor inlet shield, J 26554–A is available and must be used anytime the engine is operated with the air inlet piping removed. See Figure 9. The shield helps to prevent foreign objects from entering and damaging the turbocharger and will prevent the mechanic from accidentally touching the turbocharger impeller. The use of this shield does NOT preclude any other safety practices contained in this manual.

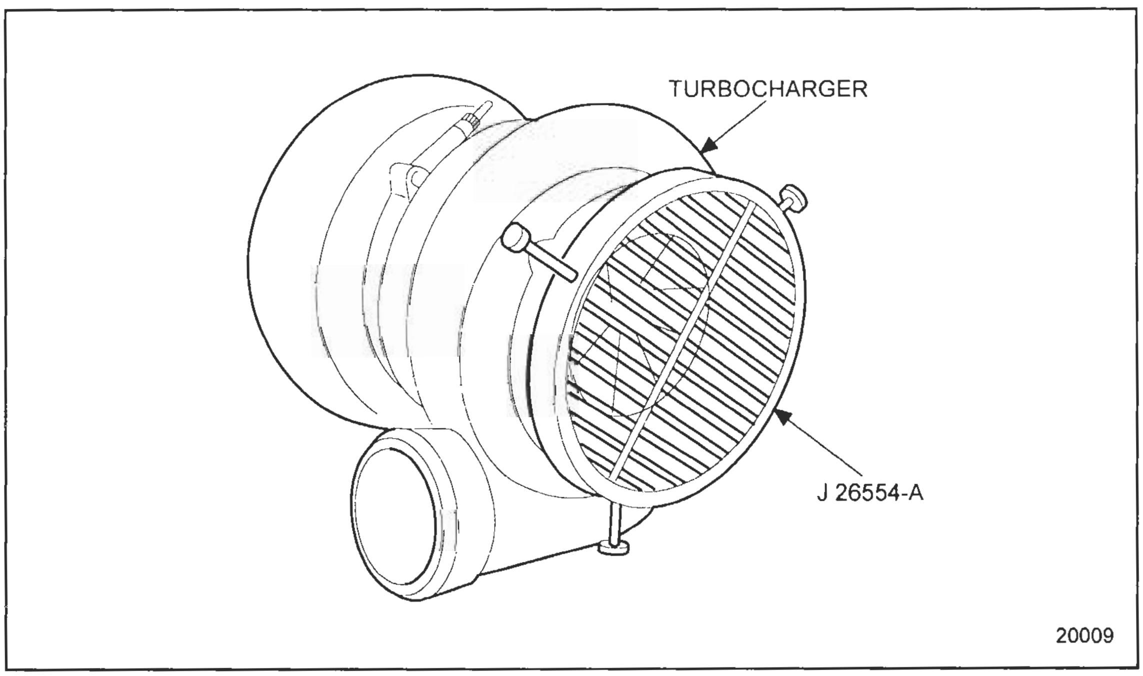


Figure 9 Turbocharger Compressor Inlet Shield, J 26554–A

FLUOROELASTOMER (VITON) CAUTION

Under normal design conditions, fluoroelastomer (*VITON*) parts, such as O-rings and seals, are perfectly safe to handle. However, a potential hazard may occur if these components are raised to a temperature above 600°F (316°C), such as during a cylinder failure or engine fire. At temperatures above 600°F (316°C) fluoroelastomer will decompose (indicated by charring or the appearance of a black, sticky mass) and produce hydrofluoric acid. This is extremely corrosive and, if touched by bare skin, may cause severe burns, sometimes with symptoms delayed for several hours.

CAUTION:

To avoid personal injury, wear goggles or a faceplate and neoprene or PVC gloves when handling fluoroelastomer O-rings or seals that have been degraded by excess heat. Make sure engine parts have cooled before handling them. If hydrogen fluoride condensate is expected, wash equipment and parts well with lime water (calcium hydroxide solution) before reusing. Discard gloves after handling degraded fluoroelastomer.

ENGINE VIEWS

Series 50 engine views. See Figure 10.

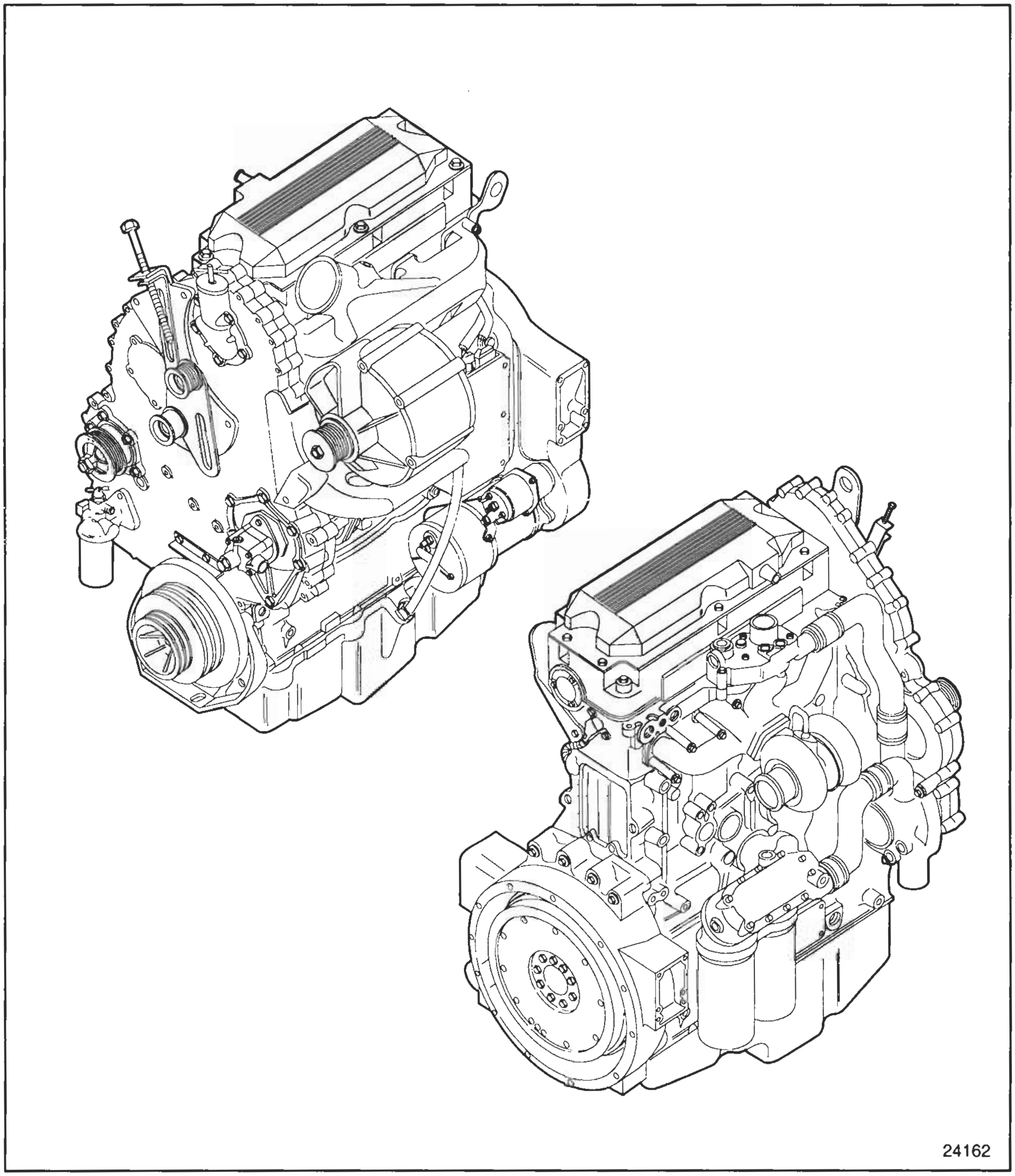


Figure 10 Engine Views

ENGLISH TO METRIC CONVERSION

Listed in Table 3 are the English to metric conversions.

Multiply Length	By	To get equivalent number of:
Inch (in.)	25.4	Millimeters (mm)
Foot (ft)	0.3048	Meters (m)
Yard (yd)	0.9144	Meters (m)
Mile (mile)	1.609	Kilometers (km)
Multiply Area	**By**	**To get equivalent number of:**
$Inch^2$ ($in.^2$)	6452	$Millimeters^2$ (mm^2)
$Inch^2$ ($in.^2$)	6.45	$Centimeters^2$ (cm^2)
$Foot^2$ (ft^2)	0.0929	$Meters^2$ (m^2)
$Yard^2$ (yd^2)	0.8361	$Meters^2$ (m^2)
Multiply Volume	**By**	**To get equivalent number of:**
$Inch^3$ ($in.^3$)	16387	$Millimeters^3$ (mm^3)
$Inch^3$ ($in.^3$)	16.387	$Centimeters^3$ (cm^3)
$Inch^3$ ($in.^3$)	0.0164	Liters (L)
Quart (qt)	0.9464	Liters (L)
Gallon (gal)	3.785	Liters (L)
$Yard^3$ (yd^3)	0.7646	$Meters^3$ (m^3)
Multiply Mass	**By**	**To get equivalent number of:**
Pound (lb)	0.4536	Kilograms (kg)
Ton (ton)	907.18	Kilograms (kg)
Ton (ton)	0.907	Tonne (t)
Multiply Force	**By**	**To get equivalent number of:**
Kilogram (kg)	9.807	Newtons (N)
Ounce (oz)	0.2780	Newtons (N)
Pound (lb)	4.448	Newtons (N)
Multiply Temperature	**By**	**To get equivalent number of:**
Degree Fahrenheit (°F)	(°F–32) ÷ 1.8	Degree Celsius (°C)
Multiply Acceleration	**By**	**To get equivalent number of:**
$Foot/second^2$ (ft/sec^2)	0.3048	$Meter/second^2$ (m/s^2)
$Inch/second^2$ ($in./sec^2$)	0.0254	$Meter/second^2$ (m/s^2)
Multiply Torque	**By**	**To get equivalent number of:**
Pound–inch (lb·in.)	0.11298	Newton–meters (N·m)
Pound–foot (lb·ft)	1.3558	Newton–meters (N·m)

Multiply Power	By	To get equivalent number of:
Horsepower (hp)	0.746	Kilowatts (kW)
Multiply Pressure or Stress	**By**	**To get equivalent number of:**
Inches of water (in. H_2O)	0.2491	Kilopascals (kPa)
Pounds/square in. (lb/in.^{2})	6.895	Kilopascals (kPa)
Multiply Energy or Work	**By**	**To get equivalent number of:**
British Thermal Unit (Btu)	1055	Joules (J)
Foot–pound (ft·lb)	1.3558	Joules (J)
kilowatt–hour (kW·hr)	3,600,000. or 3.6 x 10^6	Joules (J = one W/s)
Multiply Light	**By**	**To get equivalent number of:**
Foot candle (fc)	1.0764	Lumens/meter^2 (lm/m^2)
Multiply Fuel Performance	**By**	**To get equivalent number of:**
Miles/gal (mile/gal)	0.4251	Kilometers/liter (km/L)
Gallons/mile (gal/mile)	2.3527	Liter/kilometer (L/km)
Multiply Velocity	**By**	**To get equivalent number of:**
Miles/hour (mile/hr)	1.6093	Kilometers/hour (km/hr)

Table 3 English to Metric Conversion Table

DECIMAL AND METRIC EQUIVALENTS

Listed in Table 4 are the decimal to metric equivalents.

Fractions of an inch	Decimal (in.)	Metric (mm)	Fractions of an inch	Decimal (in.)	Metric (mm)
1/64	.015625	0.39688	33/64	.515625	13.09687
1/32	.03125	0.79375	17/32	.53125	13.49375
3/64	.046875	1.19062	35/64	.546875	13.89062
1/16	.0625	1.58750	9/16	.5625	14.28750
5/64	.078125	1.98437	37/64	.578125	14.68437
3/32	.09375	2.38125	19/32	.59375	15.08125
7/64	.109375	2.77812	39/64	.609375	15.47812
1/8	.125	3.175	5/8	.625	15.87500
9/64	.140625	3.57187	41/64	.640625	16.27187
5/32	.15625	3.96875	21/32	.65625	16.66875
11/64	.171875	4.36562	43/64	.671875	17.06562
3/16	.1875	4.76250	11/16	.6875	17.46250
13/64	.203125	5.15937	45/64	.703125	17.85937
7/32	.21875	5.55625	23/32	.71875	18.25625
15/64	.234375	5.95312	47/64	.734375	18.65312
1/4	.250	6.35000	3/4	.750	19.05000
17/64	.265625	6.74687	49/64	.765625	19.44687
9/32	.28125	7.14375	25/32	.78125	19.84375
19/64	.296875	7.54062	51/64	.796875	20.24062
5/16	.3125	7.93750	13/16	.8125	20.63750
21/64	.328125	8.33437	53/64	.828125	21.03437
11/32	.34375	8.73125	27/32	.84375	21.43125
23/64	.359375	9.12812	55/64	.859375	21.82812
3/8	.375	9.52500	7/8	.875	22.22500
25/64	.390625	9.92187	57/64	.890625	22.62187
13/32	.40625	10.31875	29/32	.90625	23.01875
27/64	.421875	10.71562	59/64	.921875	23.41562
7/16	.4375	11.11250	15/16	.9375	23.81250
29/64	.453125	11.50937	61/64	.953125	24.20937
15/32	.46875	11.90625	31/32	.96875	24.60625
31/64	.484375	12.30312	63/64	.984375	25.00312
1/2	.500	12.70000	1	1.00	25.40000

Table 4 Conversion Chart– Customary and Metric Units

SPECIFICATIONS

This section contains fastener torque specifications and pipe plug torque specifications.

Torque Specifications – Fasteners

The proper bolt and nut torque is dependent on its size. Standard (customary) nut and bolt torque specifications are listed in Table 5. The proper torque specifications for metric nuts and bolts are listed in Table 6.

Nut and Bolt Size, mm	280M or Better Torque, N·m	280M or Better Torque, lb·ft
#10–24	5–7	4–5
1/4 in.–20	9–12	7–9
1/4 in.–28	11–14	8–10
5/16 in.–18	18–23	13–17
5/16 in.–24	20–26	15–19
3/8 in.–16	41–47	30–35
3/8 in.–24	47–53	35–39
7/16 in.–14	62–68	46–50
7/16 in.–20	77–83	57–61
1/2 in.–13	96–102	71–75
1/2 in.–20	112–126	83–93
9/16 in.–12	122–136	90–100
9/16 in.–18	145–159	107–117
5/8 in.–11	186–199	137–147
5/8 in.–18	228–241	168–178
3/4 in.–10	325–339	240–250
3/4 in.–16	393–407	290–300
7/8 in.–9	556–569	410–420
7/8 in.–14	644–657	475–485
1 in.–8	789–799	580–590
1 in.–14	928–942	685–695

Table 5 Standard (Customary) Fastener Torque Specifications

Nut and Bolt Size, mm	Property Class 10.0 Torque, N·m	Property Class 10.0 Torque, lb·ft
M6 X 1.0	13–16	10–12
M8 X 1.25	30–38	22–28
M10 X 1.5	58–73	43–54
M12 X 1.75	101–126	75–93
M14 X 2.0	160–200	118–148
M16 X 2.0	245–306	181–226
M20 X 2.5	478–598	353–441

Table 6 Class 10.9 Torque Specifications for Metric Fasteners

Torque Specification – Pipe Plugs

Standard pipe plug torque specifications supporting the Series 50 engine are listed in Table 7.

Pipe Plug Size, NPTF	Torque Specifications, N·m	Torque Specifications, lb·ft
1/8 in.	14–18	10–13
1/4 in.	19–24	14–18
3/8 in.	24–31	18–23
1/2 in.	31–39	23–29
3/4 in.	45–56	33–41
1 in.	101–126	75–93
1–1/4 in.	129–161	95–119
1–1/2 in.	149–187	110–138

NOTE: Use sealant such as Pipe Plug Sealant with Teflon, J 26558–92 (Loctite 592) or equivalent on all uncoated pipe plugs.

Table 7 Standard Pipe Plug Torque Specifications

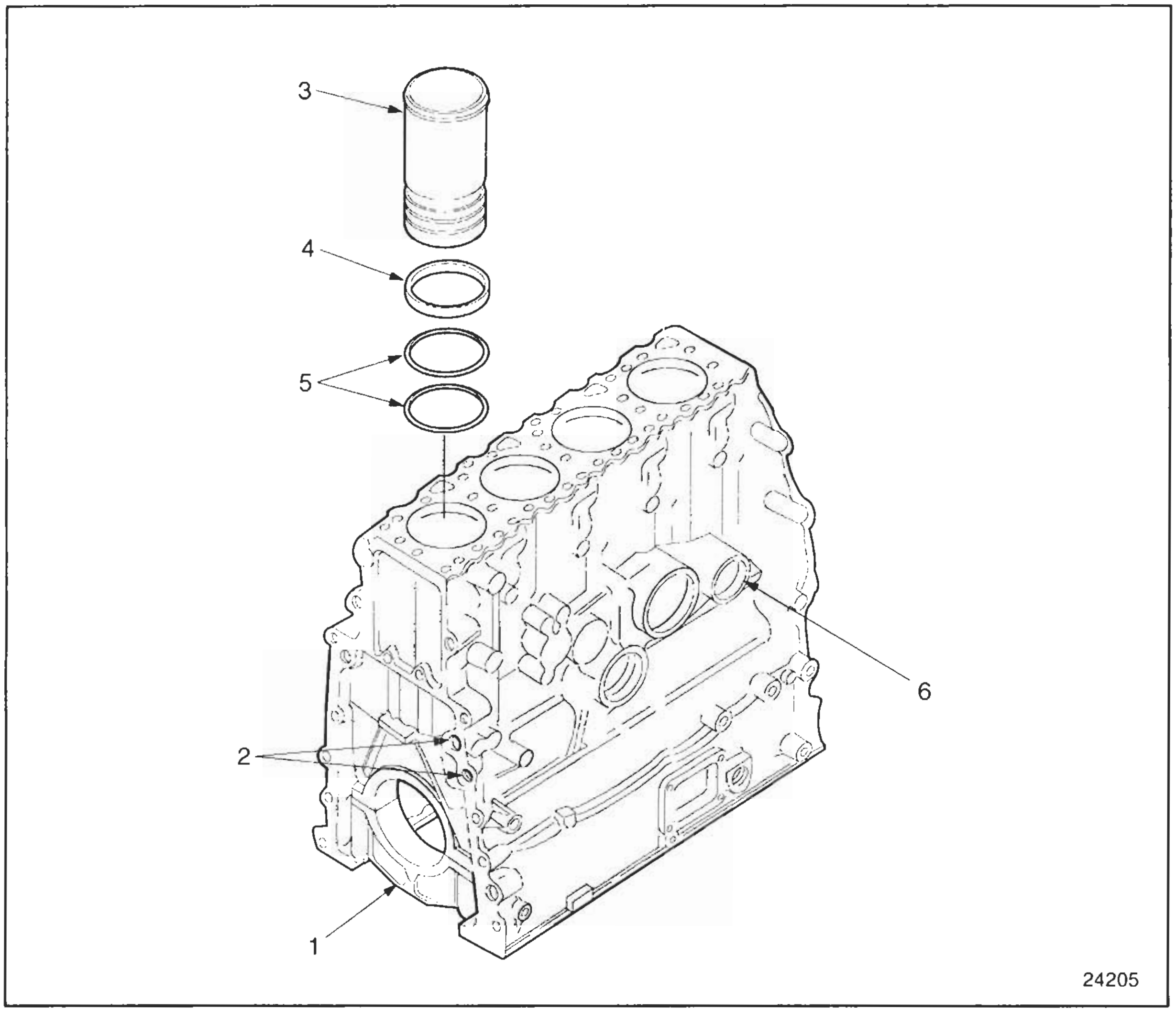
1 ENGINE

Section | Page

1.1 CYLINDER BLOCK AND CYLINDER LINER

The cylinder block is the basic engine structure, establishing and maintaining the alignment of all engine working parts. In the Series 50 Engines, the cylinder liners are not an integral part of the block casting, but are in the form of replaceable, wet type cylinder liners. See Figure 1-1.

Flanges at the liner upper ends seat in counterbores in the block deck, and project slightly above the deck to compress the head gasket for a good compression seal. Below the water jacket the lower end of the cylinder liner has two D-shaped seal rings and a lipped crevice seal to prevent leakage between the water jacket and crankcase.



1. Rear Main Bearing Cap
2. Oil Galleries
3. Cylinder Liner
4. Crevice Seal
5. D-ring Seals
6. Integral Coolant Inlet Manifold

Figure 1-1 Engine Cylinder Block and Liner

An integral coolant inlet manifold is cored into the right side of the block. It distributes the water pump output along the length of the block. Oil galleries are machined into the cooler side of the block. See Figure 1-1.

The integral oil galleries direct the oil pump output through the external oil cooler and filters, to the main oil gallery and to drilled passages in the crankcase webs which supply oil under pressure to each main bearing. In the crankcase, three integral webs plus front and rear bulkheads support the crankshaft in five main bearings. See Figure 1-2.

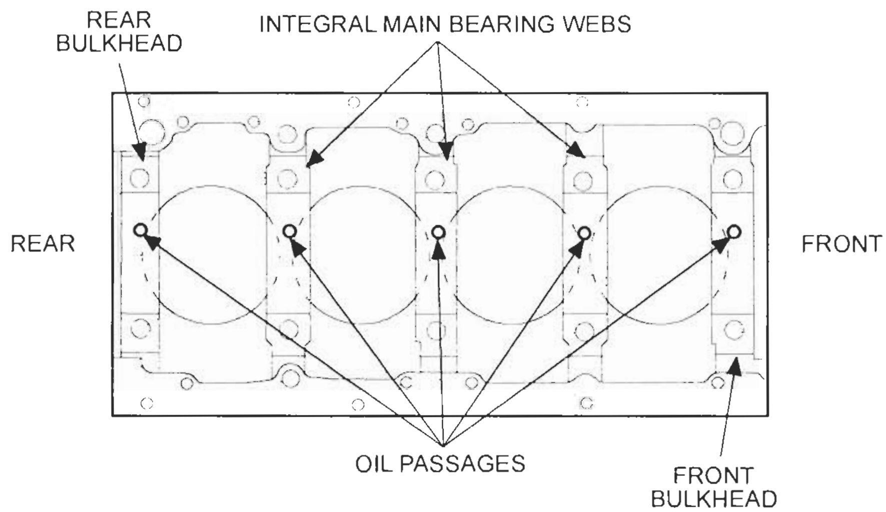


Figure 1-2 Engine Cylinder Crankcase

1.1.1 Repair or Replacement of the Cylinder Block

To determine if repair is possible or replacement is necessary perform the following procedure. See Figure 1–3.

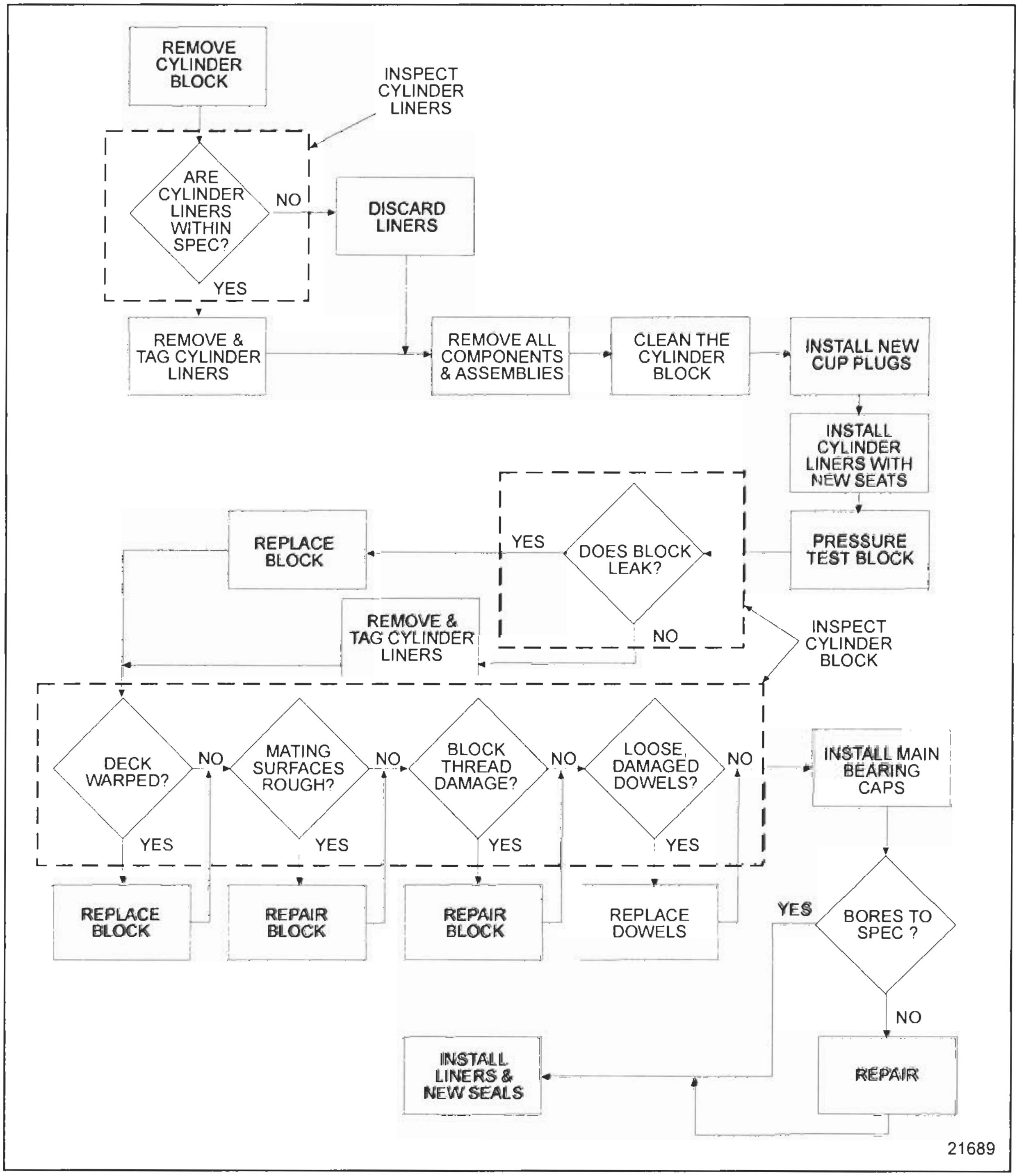


Figure 1–3 Flowchart for Repair or Replacement of Cylinder Block

1.1.2 Removal of Engine from the Vehicle and Disassembly

Before mounting an engine on an overhaul stand, it must be disconnected from the transmission. Details of removing an engine will vary from one vehicle to another. However, the following steps will be necessary, regardless of vehicle type:

1. Disconnect the battery cable(s) from the battery(s).
2. Drain the cooling system completely by removing the drain plug in the oil cooler and opening the draincocks in the cylinder block, thermostat housing and water pump housing. Refer to section 13.5.4.
3. Drain the lubricating oil. Refer to section 13.5.1.
4. Disconnect the inlet fuel line from the primary fuel filter and the outlet line from the upper fitting at the rear of the cylinder head.
5. Remove the air cleaner ducting as necessary for engine removal.
6. Remove the charge air cooler ducting from the turbocharger and intake manifold. Refer to section 6.5.2.
7. Disconnect the exhaust piping from the turbocharger.
8. Disconnect the 30–pin DDEC vehicle electrical connector and the six–pin DDEC II power connector or DDEC III five–pin power connector.
9. Disconnect and remove the cranking motor or air starter, alternator and other electrical equipment, as necessary.
10. Remove the air compressor and any air lines, as necessary.
11. Disconnect and remove the coolant hoses.
12. Remove the charge air cooler, radiator, fan guard and other cooling system related parts as necessary to remove the engine.
13. Connect a suitable lifting device to the engine using all three lifting brackets (two at the rear and one at the front).
14. Separate the engine from the transmission.
15. Remove the engine mounting bolts.

CAUTION:

To avoid personal injury and damage to the engine, a spreader bar should be used with a sling and adequate chain hoist when lifting any engine. The lifting device should be adjusted so the lifting hooks are vertical to prevent bending the engine lift brackets. To ensure proper weight distribution, all three engine lift brackets provided must be used in lifting the engine. Be sure the spreader bar is adequate to prevent lifter brackets from contacting the rocker cover, which may damage the rocker cover. Never lift an engine by any other means.

16. Lift the engine from its mounts using a suitable lifting device. See Figure 1-4.

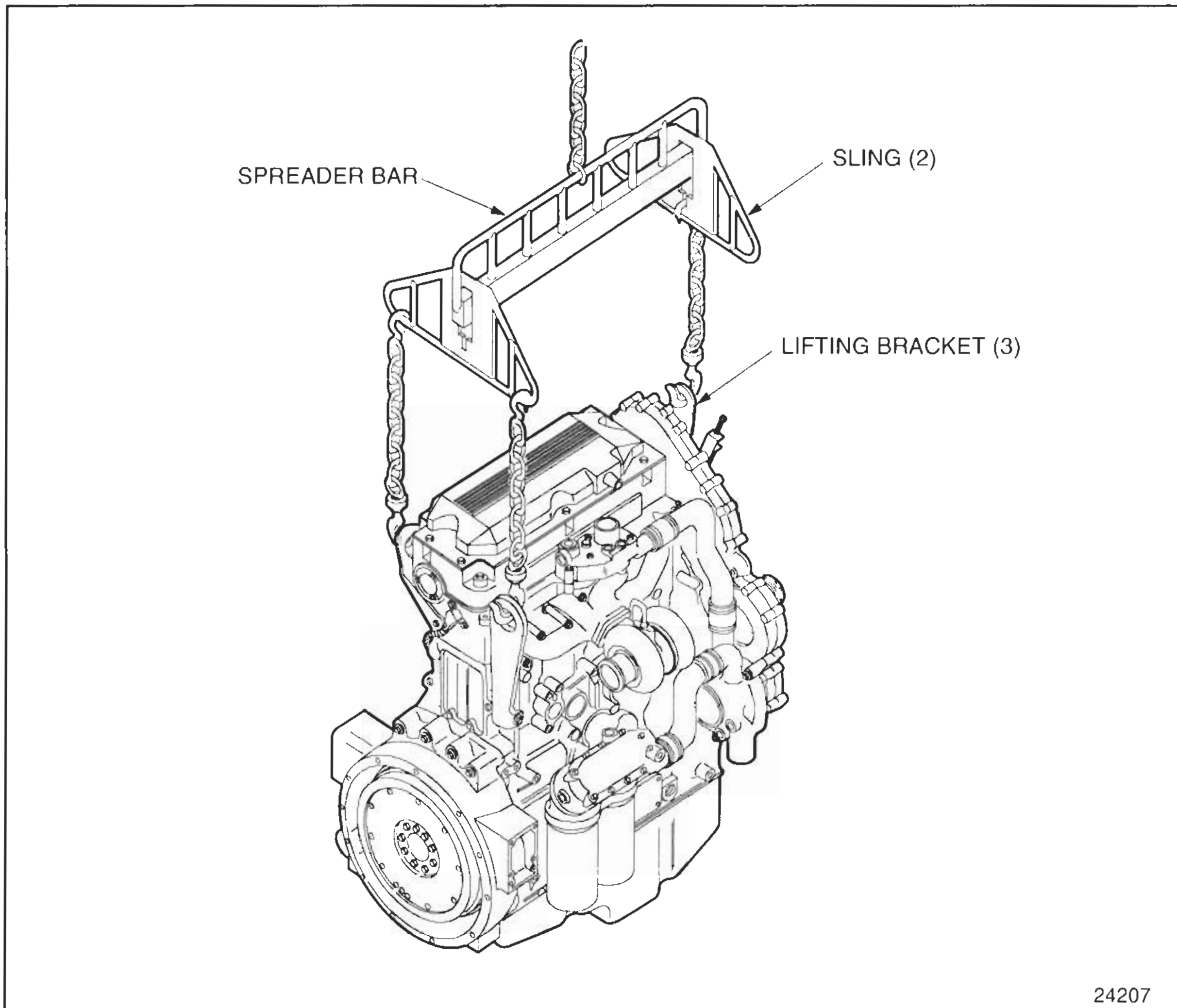


Figure 1–4 Lifting Engine

CAUTION:

Be sure the engine is securely mounted to the overhaul stand before releasing the lifting sling. Severe injury to personnel and destruction of the engine parts may result if the engine breaks away from the overhaul stand.

17. Use engine overhaul stand, J 29109, with stand adaptor plate, J 39652, for support when stripping a Series 50 Engines cylinder block. See Figure 1-5.

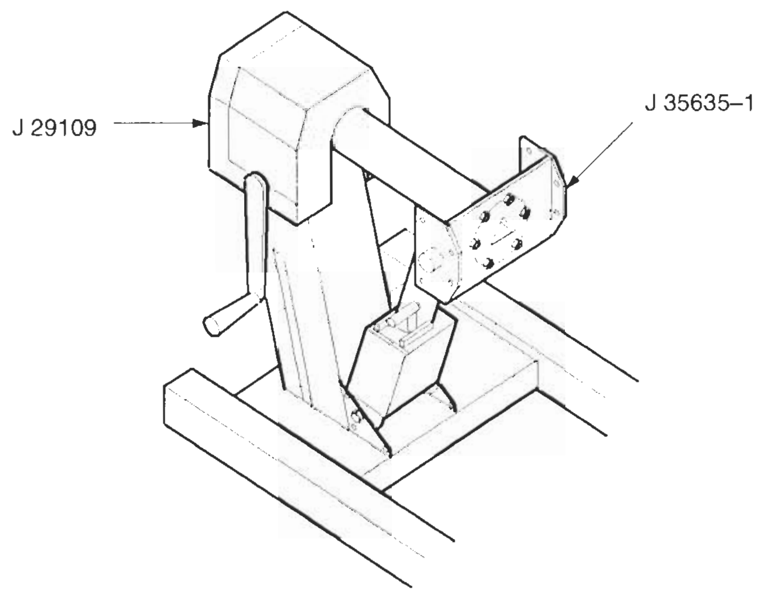


Figure 1–5 Engine Overhaul Stand and Adaptor

18. Bolt cylinder block adaptor, J 35635-2, to the cylinder block and mate it with the stand adaptor, J 39652. See Figure 1-6.

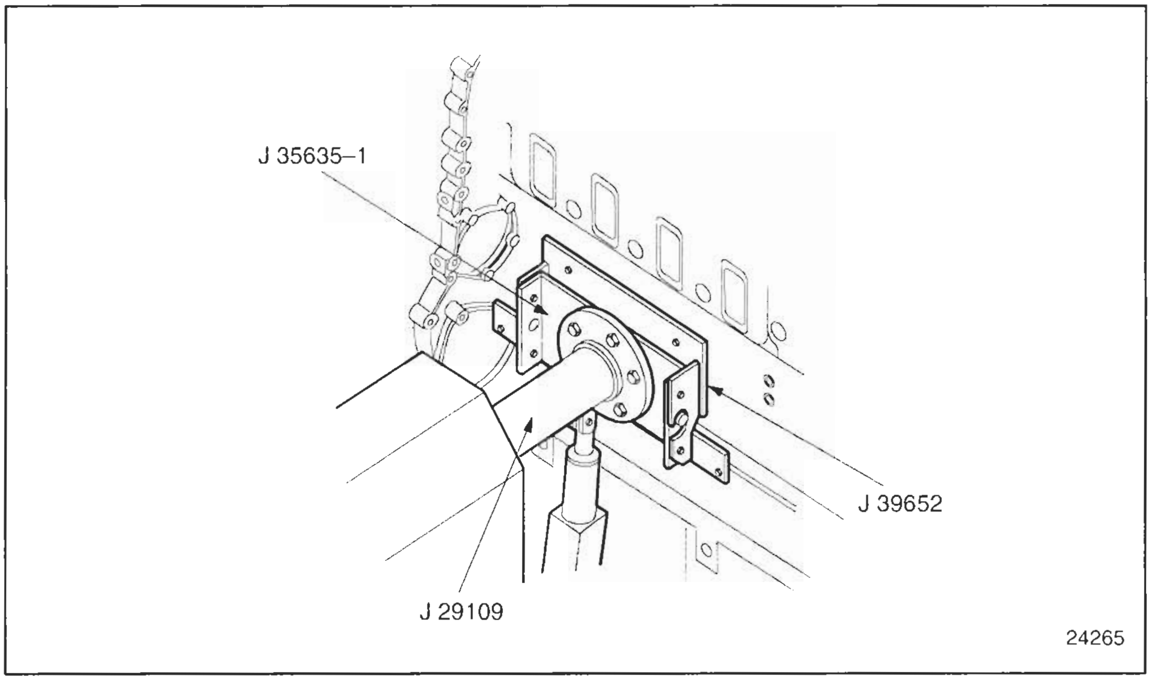


Figure 1–6 Cylinder Block Adaptor

19. The engine is left-side mounted in an upright position. Rotate it in either direction and locked into position.
20. Remove the ECM from the cold plate.
    [a] For DDEC II engines, remove the inlet and outlet fuel lines connected to the Electronic Control Module (ECM) cold plate, the ECM mounting bolts, and the ECM.

NOTE:
DDC has discontinued the use of the ECM cold plate on all Series 50 Engines. In place of the ECM cold plate, a No. 6 x 37.92 in. (963 mm) long hose assembly (23504785) is now routed from the fuel pump discharge fitting to the inlet of the secondary fuel filter.

    [b] The current DDEC III engines do not have a cold plate.
21. Disconnect the harness connector (gray) from the timing reference sensor (TRS) at the lower left corner of the gearcase. Remove the TRS from the gear case. Refer to section 2.16.2.
22. Disconnect the harness (black) connector from the synchronous reference sensor (SRS) at the left rear wall of the gearcase. Remove the SRS from the gearcase. Refer to section 2.15.2.
23. Remove any electrical components, connectors or wiring looms from the engine.

24. With the engine mounted on the overhaul stand, remove all of any remaining subassemblies and parts from the cylinder block.
    - [a] To remove the valve rocker cover, refer to section 1.6.2.
    - [b] To remove the engine lifter brackets, refer to section 1.5.2.
    - [c] To remove the crankshaft pulley, refer to section 1.13.2.
    - [d] To remove the crankshaft vibration damper, refer to section 1.12.2.
    - [e] To remove the accessory drive, refer to section 1.28.2.
    - [f] To remove the gear case cover, refer to section 1.10.2.
    - [g] To remove the camshaft drive gear, refer to section 1.23.2.
    - [h] To remove the bull gear and camshaft idler gear assembly, refer to section 1.25.2.
    - [i] To remove the adjustable idler gear assembly, refer to section 1.24.2.
    - [j] To remove the crankshaft timing gear and timing wheel, refer to section 1.26.2.
    - [k] To remove the gear case, refer to section 1.11.2.
    - [l] To remove camshaft, refer to section 1.22.2.
    - [m] To remove the cylinder head, refer to section 1.2.2.
    - [n] To remove the flywheel, refer to section 1.14.2.
    - [o] To remove the flywheel housing, refer to section 1.16.2.
    - [p] To remove the oil pan, refer to section 3.9.2.
    - [q] To remove the piston and connecting rod assembly, refer to section 1.18.2.
    - [r] To remove the cylinder liner, refer to section 1.20.2.

NOTICE:
Before removing main bearing caps, be sure each is stamped or punch–marked in numerical order, beginning with No. 1 at the front, to ensure installation in their original position. Mark all caps on the oil cooler side (right side) of the engine to prevent reversal at assembly. Failure to mark numerical order may result in the caps being put back in incorrect order.

    - [s] To remove the crankshaft, refer to section 1.7.2.
    - [t] To remove the crankshaft main bearings, refer to section 1.9.2.

1.1.3 Cleaning the Cylinder Block

Before removing cylinder liners for block cleaning, the liner bores should be gaged to determine whether liner replacement is necessary. Refer to section 1.20.2.1.

Remove cylinder liners with the cylinder liner removal tool, J 35791, before putting the block in cleaning or describing baths, to avoid trapping cleaning agents in block liner seating bores. See Figure 1-7.

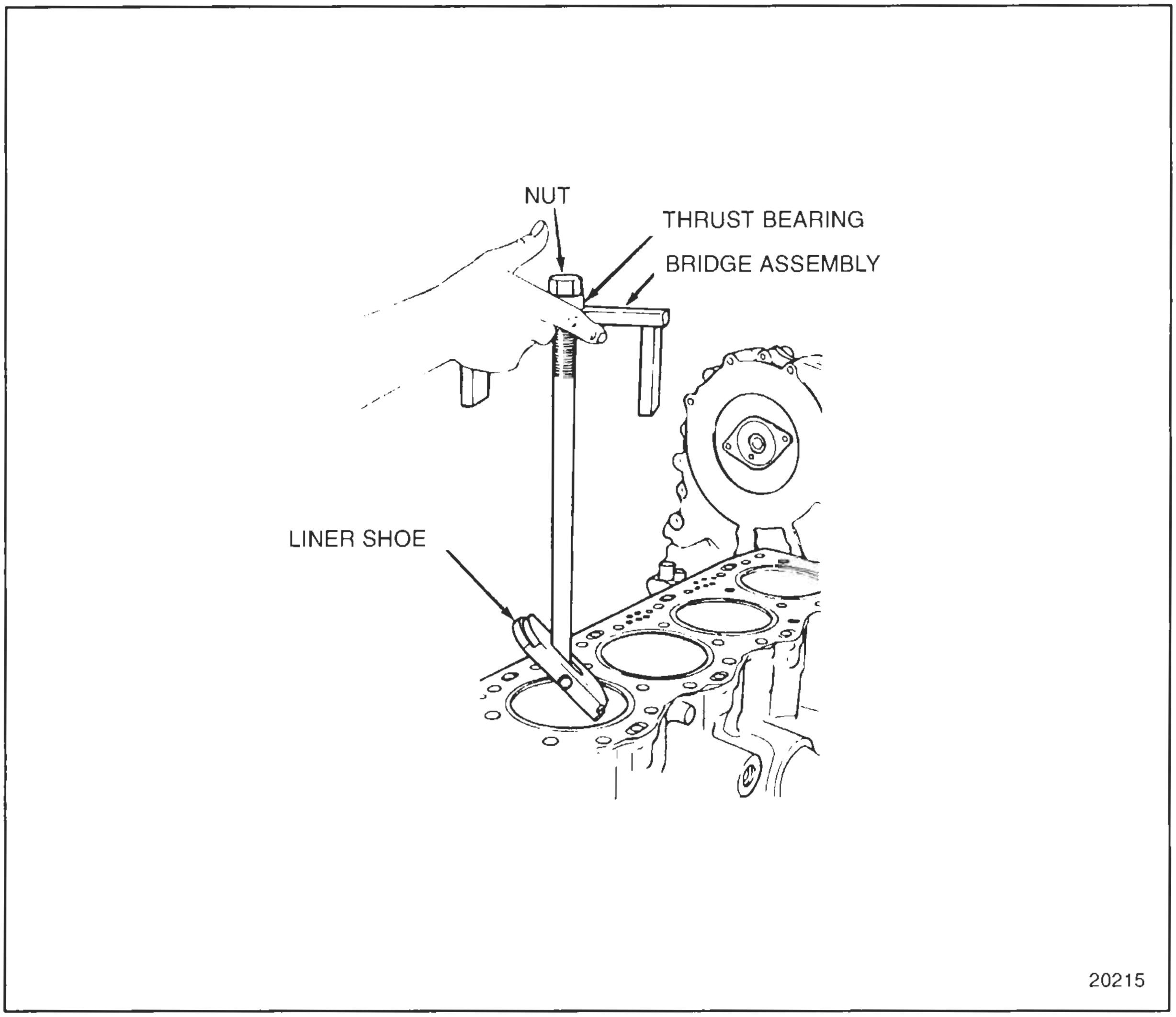


Figure 1–7 Cylinder Liner Removal Tool

After disassembling and before removing the cylinder block from the overhaul stand for cleaning and inspection, install the two metric eye bolts J 35595 to the cylinder block.

Clean the cylinder block as follows:

1. Remove all oil and water gallery and weep hole plugs to allow the cleaning solution to enter the inside of the oil and water passages.

2. Using two metric eye bolts, J 35595, installed in the head bolt holes at opposite ends of the block, and with a suitable lifting device and spreader bar, immerse and agitate the block in a hot bath of a commercial, heavy–duty alkaline solution.
3. Wash the block in hot water or steam clean it to remove the alkaline solution.
4. If the water jackets are heavily scaled, proceed as follows:
   [a] Agitate the block in a bath of inhibited phosphoric acid.
   [b] Allow the block to remain in the acid bath until the bubbling action stops (approximately 30 minutes).
   [c] Lift the block, drain it and reimmerse it in the same acid solution for 10 more minutes. Repeat until all scale is removed from the water jacket area.
   [d] Rinse the block in clear, hot water to remove the acid solution.
   [e] Neutralize the acid that may cling to the casting by immersing the block in an alkaline bath.
   [f] Wash the block in clean water or steam clean it.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

5. Dry the cylinder block with compressed air. Blow out all of the bolt holes and passages with compressed air.

NOTE:
The above cleaning procedure may be used on all ordinary cast iron and steel parts for the engine. Aluminum parts, such as flywheel housing, air intake manifold, oil filter adaptor and the camshaft gear access cover should NOT be cleaned in this manner. Mention will be made of special procedures when necessary.

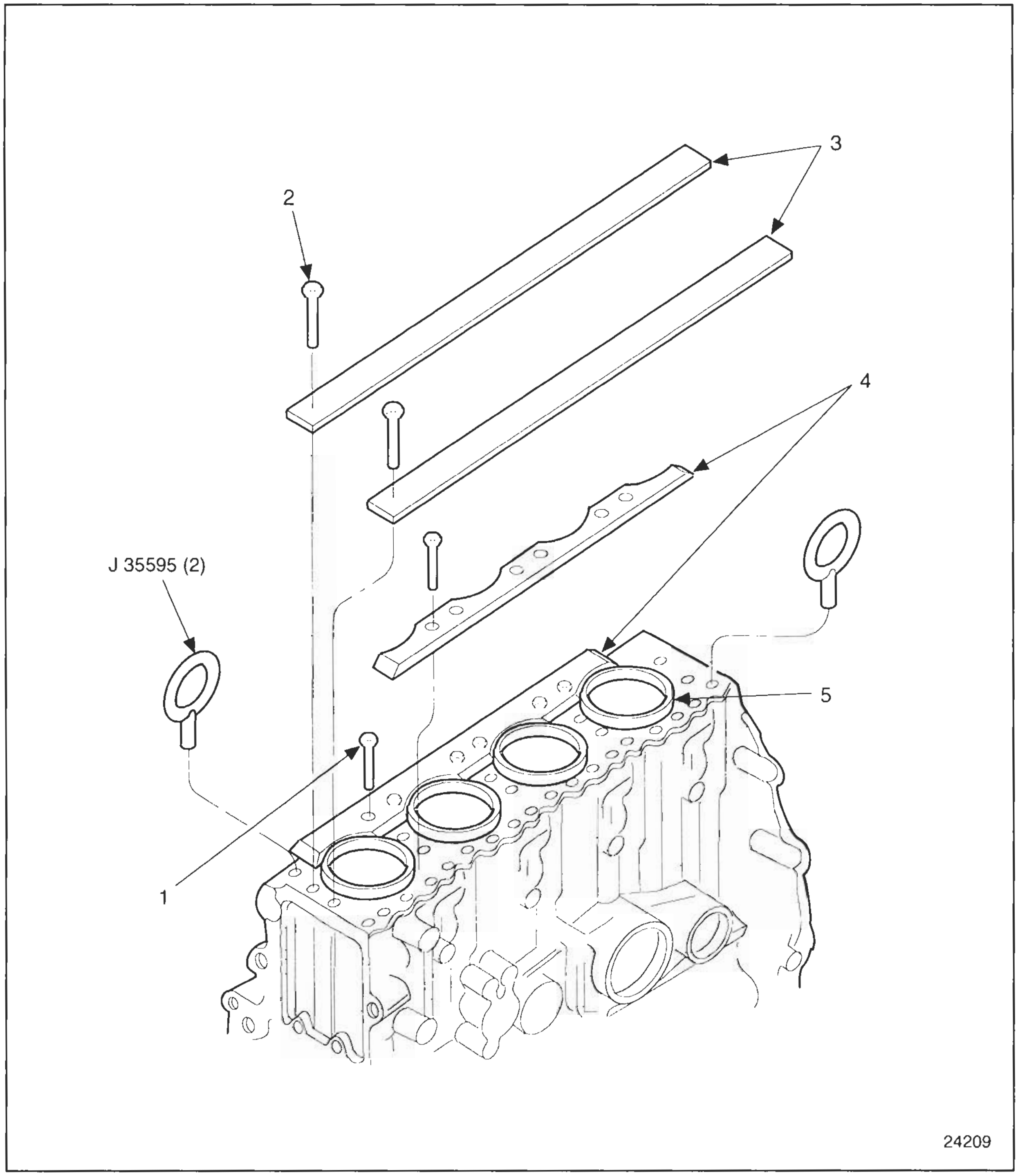
6. Be certain that all water passages and oil galleries have been thoroughly cleaned and dried. Install weep hole plugs and precoated pipe plugs. Install new cup plugs using a coating of good grade non–hardening sealant such as Loctite 620 or equivalent.

7. Pressure test the cylinder block. Two methods of cylinder block pressure testing may be used depending on the test facilities available:
   [a] Immersion method; refer to section 1.1.3.1.
   [b] Leak–marker method; refer to section 1.1.3.2.

1.1.3.1 Cylinder Block Immersion Method Pressure Testing

Use cylinder block pressure test kit, for immersion method pressure testing as follows:

1. Install cylinder liners with new seal rings and crevice seals. Refer to section 1.20.3. Seat the liners firmly in the block counterbores with cylinder liner installation tool, J 35597.
2. Install two metric eye bolts, J 35595, in the head bolt holes at opposite ends of the block. See Figure 1-8.



1. Bolts (12)
2. Bolts (10)
3. Outside Test Strips (2)
4. Test Strips (2)
5. Test Rings (5)

Figure 1–8 Cylinder Block Test Deck Plate Installation

3. Install the cylinder block test strips and rings. See Figure 1-8.
4. Install the bolts through the strips and into the cylinder block. Tighten the bolts on the ring strips to 230–237 N·m (170–175 lb·ft) torque. Tighten the bolts on the outside strips to 14 N·m (10 lb·ft) torque.
5. Install the water inlet cover plate, J 36223-7A. See Figure 1-9. Use the bolt supplied with the tool to secure it to the cylinder block.

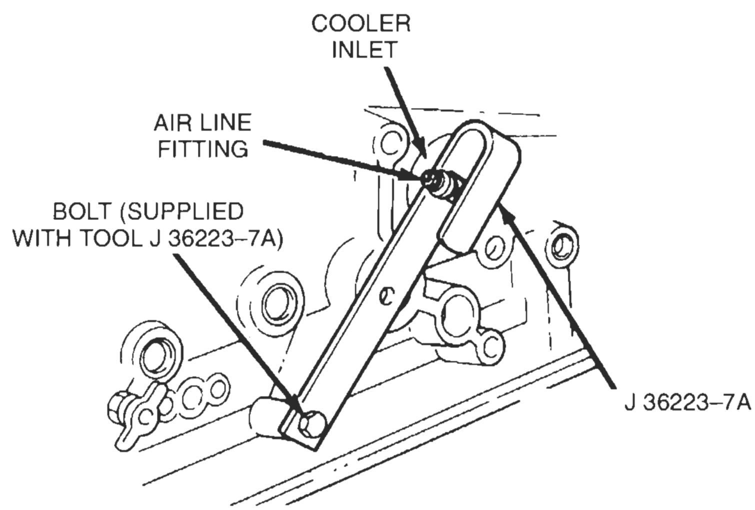


Figure 1–9 Water Inlet Cover Plate Installation

NOTE:
At the base of each liner, the space between upper and lower liner seals is vented to the block surface, on the left side. Any coolant leakage past the upper seal is drained to the outside rather than into the crankcase, and is easily detected by a visual inspection.

6. With a suitable lifting device and spreadable bars, immerse the cylinder block for twenty minutes in a tank of water heated to 82–93°C (180–200°F).
7. Attach an air line to the water inlet cover plate and apply 138 kPa (20 lb/in.^{2}) air pressure to the water jacket. Observe the water in the tank for bubbles that will indicate cracks or leaks. A cracked cylinder block must be replaced by a new block.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

8. Remove the block from the water tank. Remove the plates and gaskets and blow out all of the passages in the block with compressed air.
9. Remount the cylinder block to the engine overhaul stand, J 29109.

1.1.3.2 Cylinder Block Leak–Marker Pressure Testing

When a large water tank is not available, or when it is desired to check the block for cracks without removing the engine from the vehicle cylinder block leak–marker pressure testing may be used.

1. Install cylinder liners with new seal rings and crevice seals. Refer to section 1.20.3. Seat the liners firmly in the block counterbores with cylinder liner installation tool, J 35597.
2. Install two metric eye bolts, J 35595, in the head bolt holes at opposite ends of the block. See Figure 1–8.
3. Fill the water jacket with a mixture of water and 3.8 liters (1 U.S. gallon) of permanent–type antifreeze. The antifreeze will penetrate small cracks and its color will aid in detecting their presence.
4. Install the cylinder block test strips and rings. See Figure 1–8.
5. Install the bolts through the strips and into the cylinder block. Tighten the bolts on the ring strips to 230–237 N·m (170–175 lb·ft) torque. Tighten the bolts on the outside strips to 14 N·m (10 lb·ft) torque.
6. Install the water inlet cover plate, J 36223–7A. See Figure 1–9. Use the bolt supplied with the tool to secure it to the cylinder block.

NOTE:
At the base of each liner, the space between upper and lower liner seals is vented to the block surface, on the left side. Any coolant leakage past the upper seal is drained to the outside rather than into the crankcase, and is easily detected by a visual inspection.

7. With a suitable lifting device and spreadable bars, immerse the cylinder block for twenty minutes in a tank of water heated to 82–93°C (180–200°F).
8. Apply 138 kPa (20 lb/in.^{2}) air pressure to the water jacket and maintain this pressure for at least two hours to give the water and antifreeze mixture ample time to work its way through any cracks which may exist.

9. At the end of this test period, examine the outside diameter area of the liner flanges, oil passages, crankcase and exterior of the block for presence of the water and antifreeze mixture, which will indicate the presence of cracks. A cracked cylinder block must be replaced with a new block.

> **CAUTION:**
>
> **To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.**

10. After the pressure test is completed, remove the test deck plate and gasket and the water inlet cover plate. Drain the water jacket. Then blow out all of the passages in the cylinder block with compressed air.

11. Remount the cylinder block to the engine overhaul stand, J 29109.

1.1.4 Cylinder Block Inspection Procedures

Perform the following preliminary step prior to performing cylinder block inspections:

1. Remove the cylinder liners and regage to determine whether liner replacement is necessary. Refer to section 1.20.2.

1.1.4.1 Inspection of the Cylinder Block

Perform the following for cylinder block inspection:

1. Measure the bore of each cylinder with cylinder bore gage, J 5347–B, which has a dial indicator calibrated in 0.0001 in. increments. See Figure 1–10.

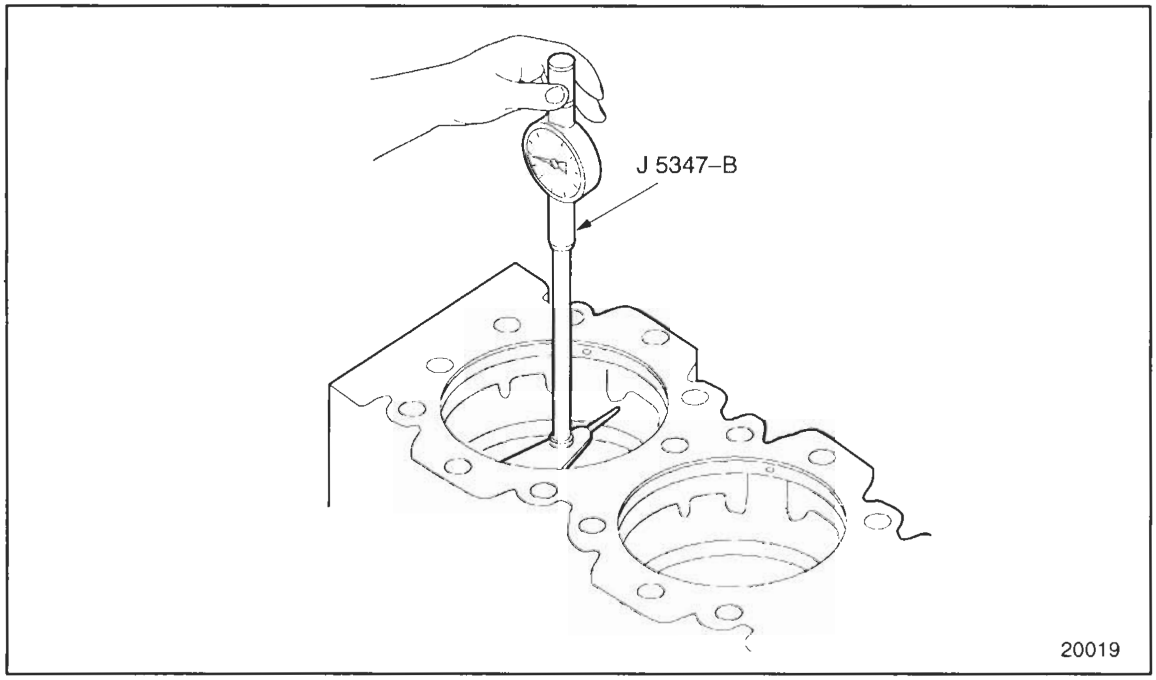


Figure 1–10 Gaging Cylinder Bores

2. Measure cylinder block bore, at the positions on axis 90° apart. See Figure 1-10. If the diameter does not exceed the dimensions listed in Table 1-1, the block may be reused.

NOTE:
The above measurements are average gage readings at each position. Also, the out–of–round must not exceed 0.0254 mm (.001 in.). See Figure 1–11.

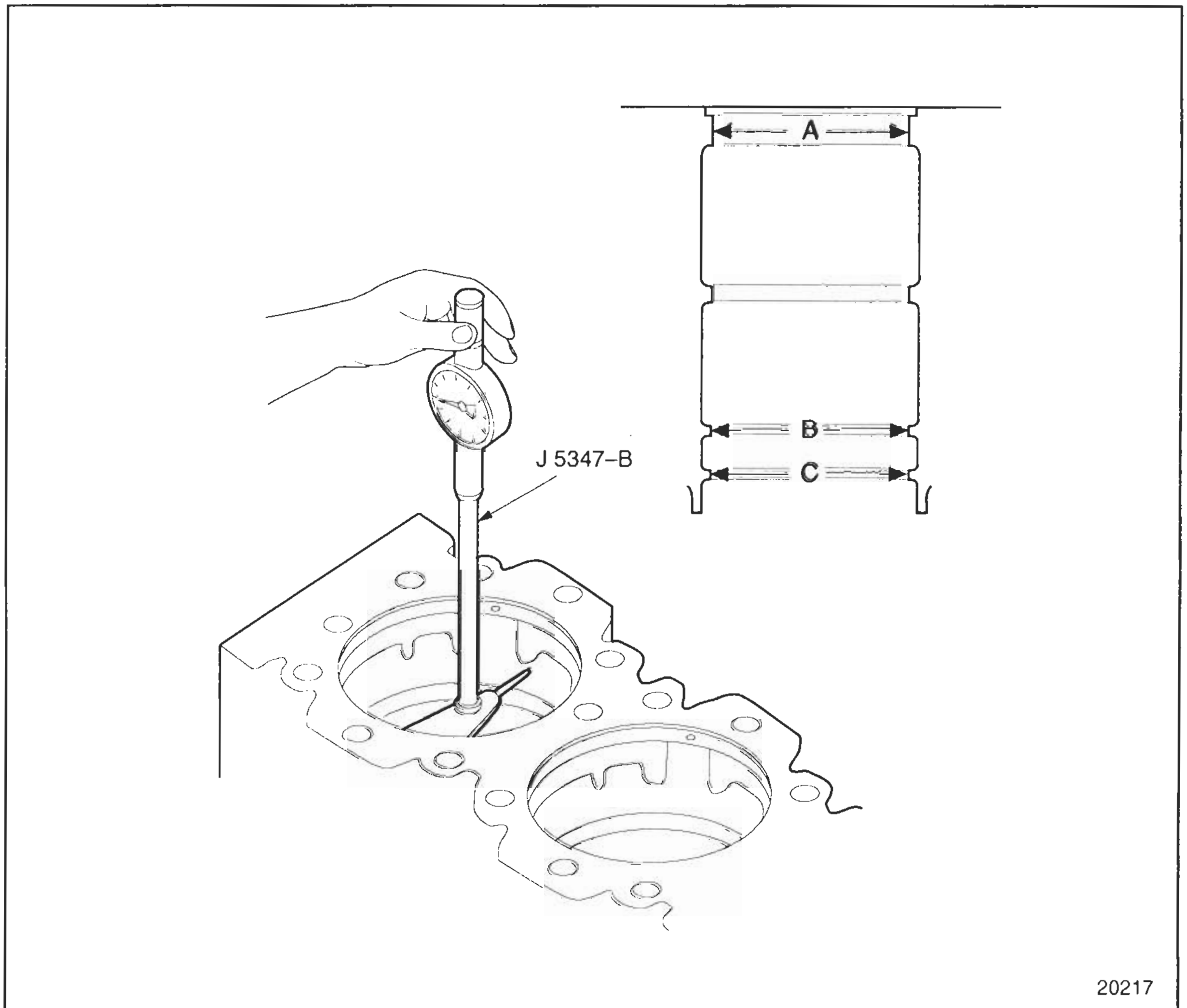


Figure 1–11 Maximum Cylinder Block Bore Diameters by Location (After Clean–up)

Location	Diameter, mm	Diameter, in.
A	149.050–149.120	5.686–5.871
B	146.050–146.120	5.750–5.753
C	146.050–146.120	5.750–5.753

Table 1–1 Acceptable Cylinder Bore Diameters

1.1.4.2 Inspection of Deck Flatness

Check the cylinder block deck for flatness with an accurate straightedge and feeler gage. See Figure 1-12.

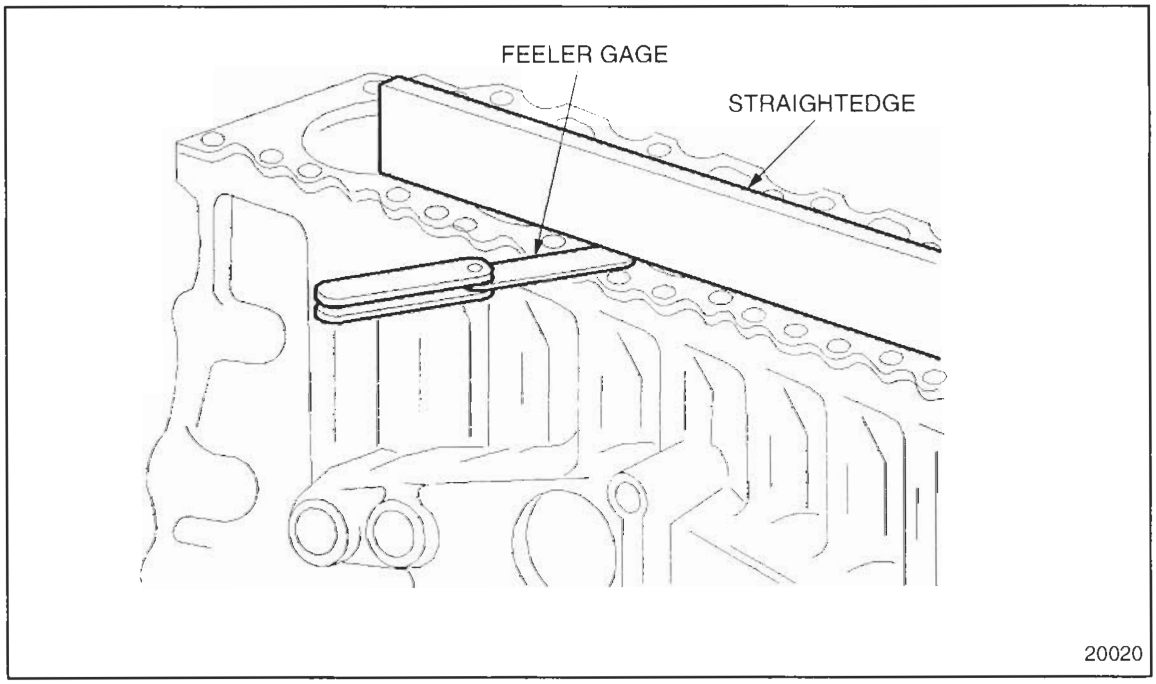


Figure 1-12 Checking Block Deck for Flatness

Check front-to-rear flatness next to the cylinder liner flanges on both sides, and side-to-side flatness between the liner flanges. The deck must be flat within 0.120 mm (.005 in.) front-to-rear, and flat within 0.076 mm (.003 in.) side-to-side. If not, the deck must be resurfaced.

NOTICE:
The camshaft is mounted in the cylinder head so resurfacing of the block head affects the position of the camshaft in relation to the adjustable idler gear and gear train.

Record the amount of stock removed from the cylinder block by stamping the amount removed on the cylinder block pad. See Figure 1–13.

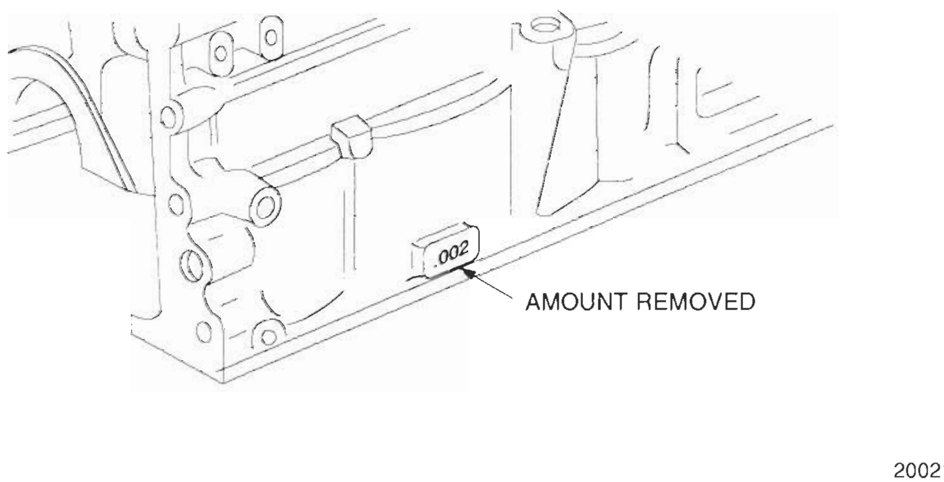


Figure 1–13   Recording Stock Removal on Cylinder Block

1.1.4.3 Inspection of Main Bearing Bores

Perform the following steps for main bearing bore inspection:

1. Install the main bearing caps in their original positions. Lubricate the cap bolt threads and head contact surfaces with a small quantity of International Compound No. 2.
2. Install the main cap bolts and torque to 470–530 N·m (347–391 lb·ft).
3. Measure the main bearing bores using dial bore gage J 5347–B which has a dial indicator calibrated in .0001 in. increments. Set the cylinder bore gage on zero in master setting fixture, J 23059–01.
   See Figure 1–14.

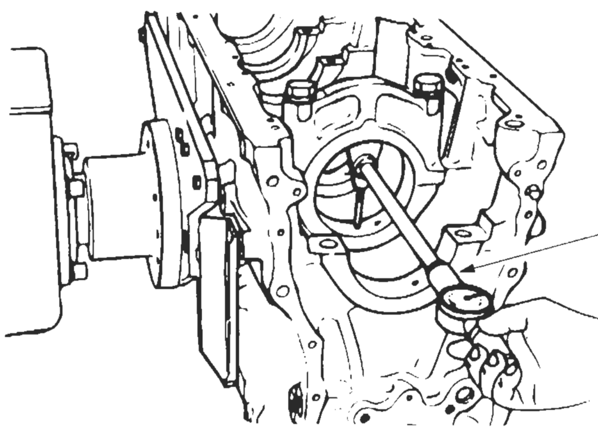


Figure 1–14 Gaging Main Bearing Bores

NOTE:
Dial bore master setting fixture should be used to zero the cylinder bore gage.

The bore diameter specification is 132.994–133.031 mm (5.236–5.237 in.). An oversize main bearing bore may be line-bored to accept a .508 mm (0.040 in.) oversize O.D. main bearing. Line boring is also necessary when a bearing cap must be replaced due to breakage or spun-bearing damage. Refer to section 1.A for line boring specifications which are listed in Table 1–10.

1.1.4.4 General Inspection

Check all machined surfaces for nicks or burrs that could affect the fit of mating parts. Clean up as necessary by stoning. Also inspect all tapped holes for thread damage and retap or install helical thread inserts as necessary. Replace any loose or damaged dowel pins.

1.1.4.5 Rust Prevention

After inspection, if the cylinder block is not to be used immediately, spray the machined surfaces with engine oil.

NOTICE:
Castings free of grease or oil will rust when exposed to the atmosphere. Rust on machined surfaces may result in leakage.

If the block is to be stored for extended period of time, spray or dip it in a polar-type rust preventative. Castings which are free of grease or oil will rust when exposed to the atmosphere.

1.1.5 Reassembly of Cylinder Block

After the cylinder block has been cleaned and inspected, assemble the engine as follows:

CAUTION:
To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

1. If a reconditioned or new service replacement cylinder block is used, steam clean it to remove the rust preventive and blow out the oil galleries with compressed air.
2. If a new service replacement block is used, stamp the engine serial number and model number on the pad provided on the left side of the block, just below the deck. See Figure 1-15.

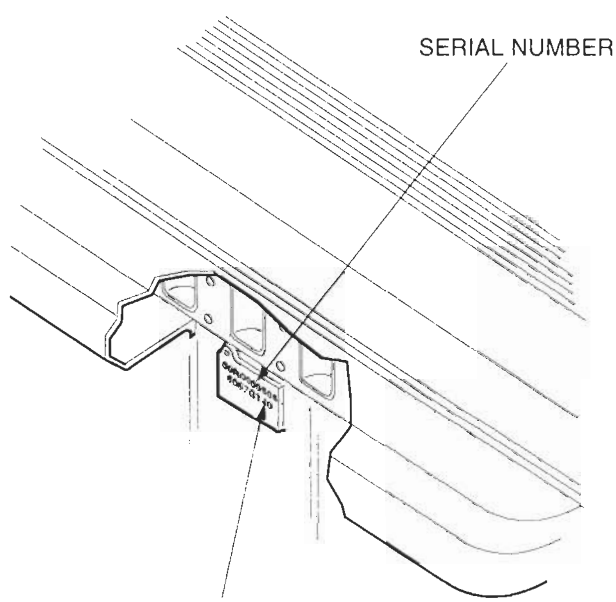


Figure 1–15 Location of Engine Serial and Model Numbers

3. Also stamp the position numbers on the main bearing caps and the position of the No. 1 bearing on the cooler side of the oil pan mounting flange of the block.
4. Install the main bearing caps in their original positions; refer to section 1.9.3.

5. Install all of the required cup plugs. Use a good grade of non–hardening sealant such as Loctite 620 (or equivalent). Apply a thin coat of sealant just inside the chamfer where the plug is to be installed and install using cup plug installation tool set, J 35653. See Figure 1–16.

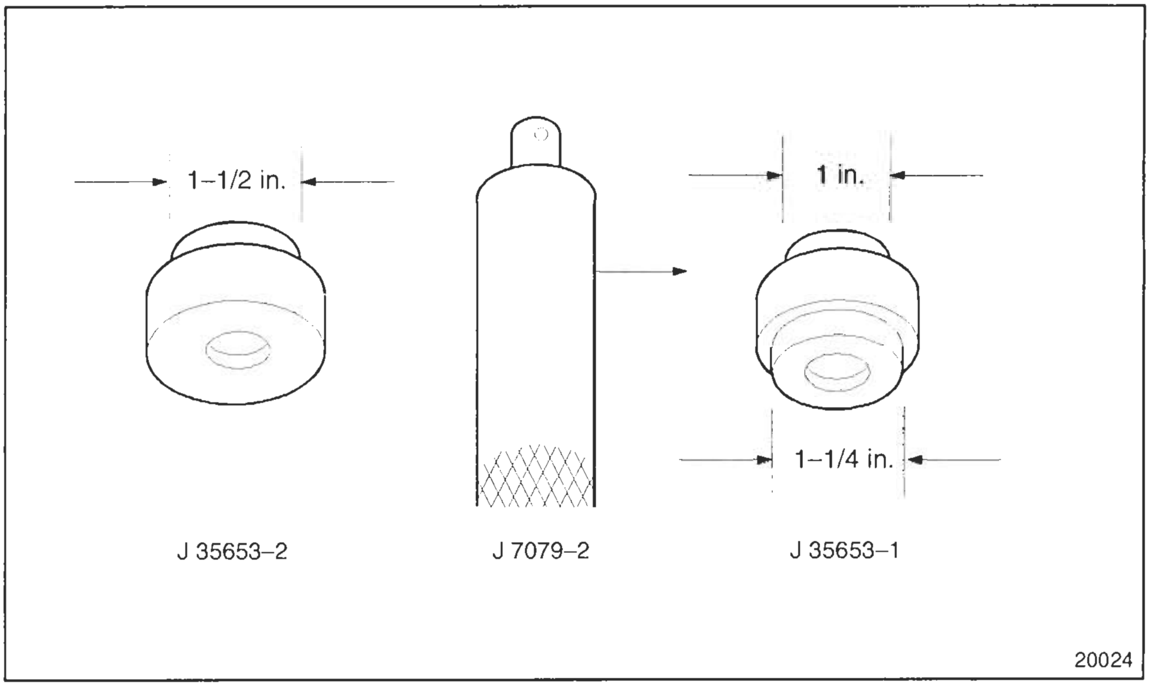


Figure 1–16 Cup Plug Installation Tool Set

6. Install all of the required pipe plugs.

NOTE:
Whenever a pipe plug is installed, the threads must be coated with Loctite, J 26558–92, pipe sealant with Teflon, or equivalent, before reassembly. Certain plugs available from the parts depot already have a sealer applied to the threads. Although unnecessary, this pre–coating will not be affected if pipe sealer with Teflon is also applied.

7. Install the crankshaft main bearings, refer to section 1.9.3.
8. Install the crankshaft, refer to section 1.7.3.
9. Install cylinder liners if removed, refer to section 1.20.3.
10. Install the piston and connecting rod assembly, refer to section 1.18.5.
11. Install the oil pan, refer to section 3.9.3.
12. Install the flywheel housing, refer to section 1.16.3.
13. Install the flywheel, refer to section 1.14.3.
14. Install the cylinder head, refer to section 1.2.5.
15. Install the camshaft, refer to section 1.22.5.
16. Install the gear case, refer to section 1.11.3.
17. Install crankshaft timing gear and timing wheel, refer to section 1.26.3.

18. Install the adjustable idler gear assembly, refer to section 1.24.3.
19. Install bull gear and camshaft idler gear assembly, refer to section 1.25.3.
20. Install the camshaft drive gear, refer to section 1.23.3.
21. Install the gear case cover, refer to section 1.10.3.
22. Install the accessory drive, refer to section 1.28.5.
23. Install the vibration damper, refer to section 1.12.3.
24. Install the crankshaft pulley, refer to section 1.13.3.
25. Install the engine lifter brackets, refer to section 1.5.3.
26. Install the valve rocker cover, refer to section 1.6.4 and refer to section 1.6.5.
27. Install any electrical components, connectors or wiring looms that were removed during disassembly.
28. Install the SRS synchronous reference sensor, refer to section 2.15.3.
29. Install the TRS timing reference sensor, refer to section 2.16.3.
30. Install the ECM electronic control module and cold plate if required. Refer to section 2.9.3 for DDEC III ECMs; refer to section 2.10.4 for DDEC II ECMs.
31. Install a suitable lifting device to the engine. See Figure 1–4.

CAUTION:

Be sure the engine is securely mounted to the overhaul stand before releasing the lifting sling. Severe injury to personnel and destruction of the engine parts may result if the engine breaks away from the overhaul stand.

32. Remove the engine from the engine overhaul stand. See Figure 1–5.

Transfer the engine to an engine dynamometer test stand. Operate the engine following the Run–In procedure; refer to section 11.6.2.

Reinstall the engine in the equipment from which it was removed.

1.2 CYLINDER HEAD

The Series 50 Engines cylinder head combines intake and exhaust valve porting and fuel injector seats with water jacketing to cool the ports, injectors and combustion chamber area. See Figure 1-17.

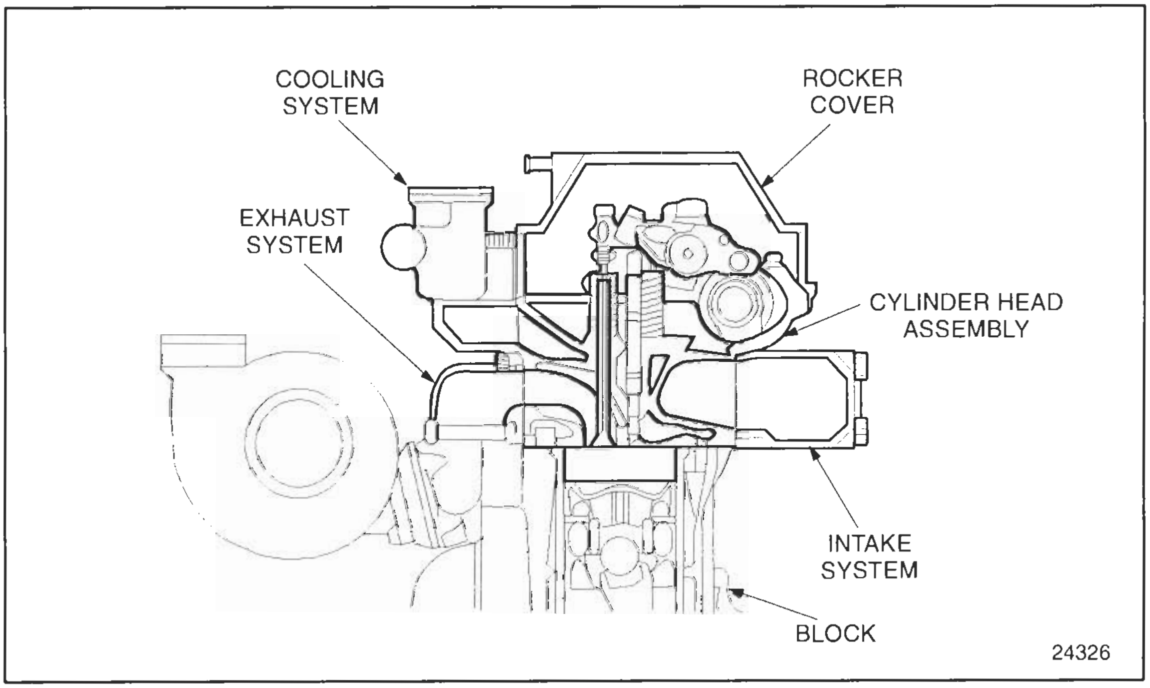
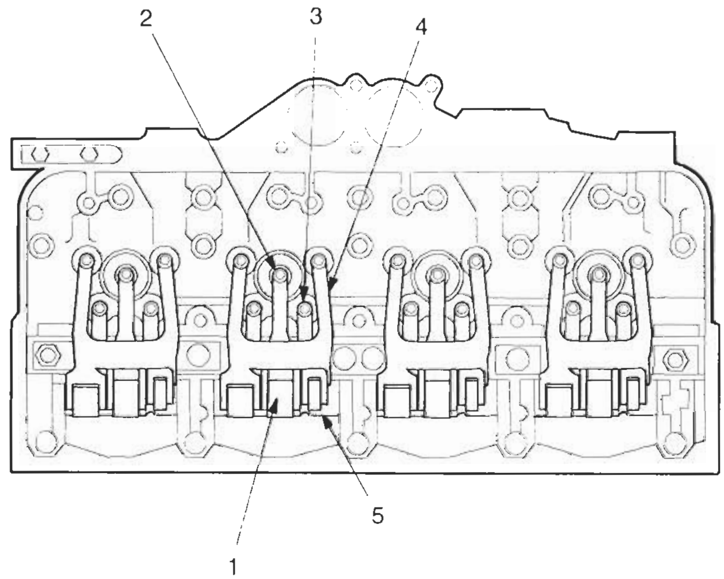


Figure 1–17 Cylinder Head Assembly and Mating Components

With the overhead camshaft design, the cylinder head assembly includes:

- Cylinder head
- Valve and injector operating mechanism
- Injector, valve guide and related parts
- Camshaft and camshaft bearings

The nested roller follower type rocker arms transmit cam motion directly to the valves and injectors. See Figure 1-18.



1. Roller Follower
2. Injector Rocker Arm
3. Intake Valve Rocker Arm
4. Exhaust Valve Rocker Arm
5. Camshaft

Figure 1–18 Cylinder Head Assembly

The porting within the cylinder head is cross-flow, with intake and exhaust ports on opposite sides for minimum restriction and maximum exposure to coolant flow. Four valves are used per cylinder, two intake and two exhaust. See Figure 1-19.

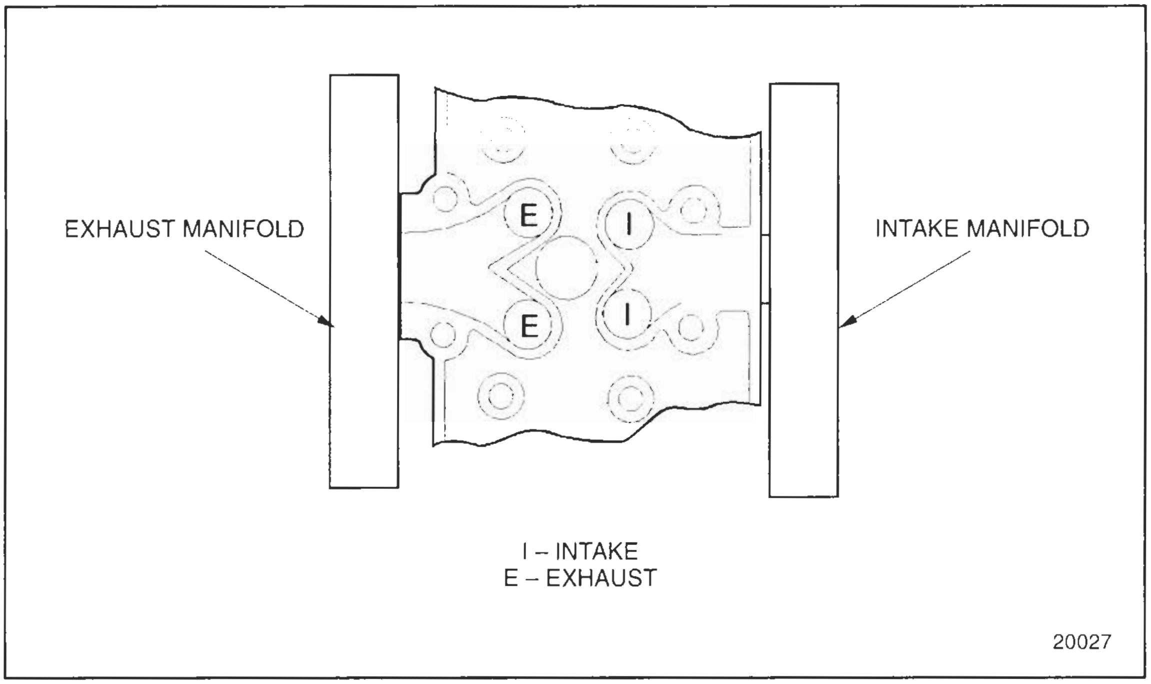
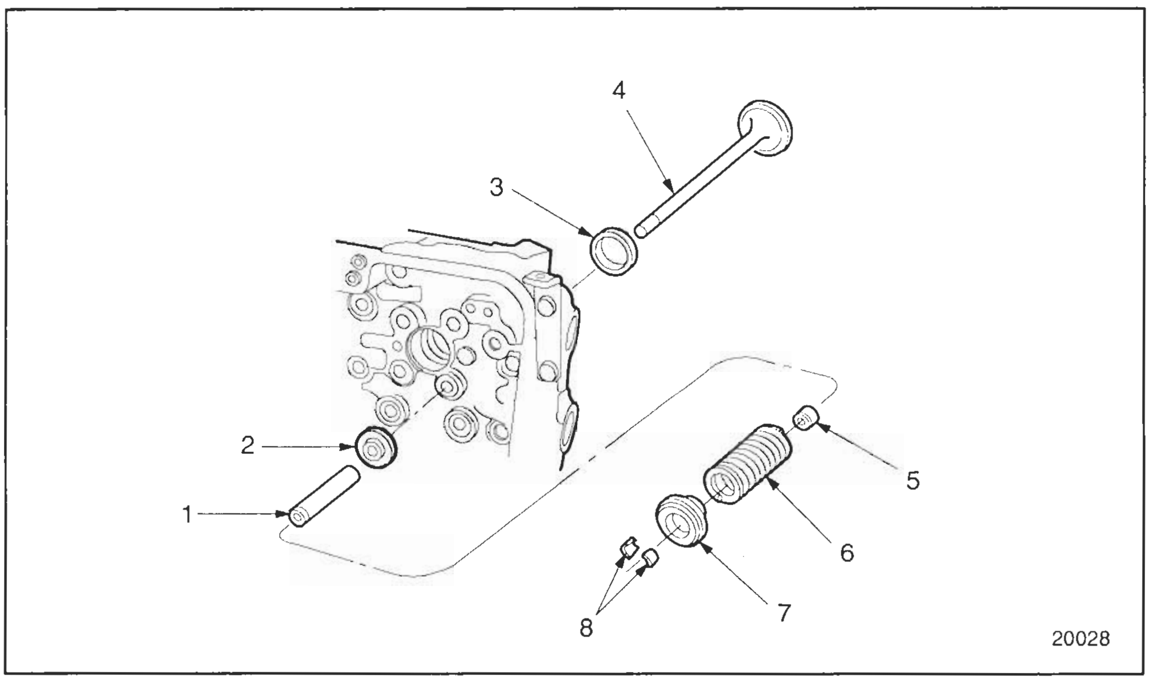


Figure 1–19 Intake and Exhaust Valve Porting

Replaceable valve guides, valve spring seats, valve stem seals, valve rotators and valve seat insert are used on all valves. See Figure 1–20.



1. Valve Guide
2. Valve Spring Seat
3. Valve Seat Insert
4. Valve
5. Valve Stem Oil Seal
6. Valve Spring
7. Valve Rotator
8. Valve Keepers

Figure 1–20 Valve, Valve Guides and Related Parts

Copper injector tubes (not required on natural gas engines) extending through the cylinder head water jacket are required for the fuel injectors. The tubes are directly exposed to the coolant. An O-ring seals the injector tube upper end in the recess. The lower end of the injector tube must be expanded and flared during the installation process to contain a tight fit in the firedeck bore. A beveled seat machined in the tube provides a compression-tight seal when the injector is seated, as well as affording effective heat transfer facilitating injector cooling. Refer to section 2.3.

Fuel galleries machined into the head supply fuel under fuel pump pressure to all injectors, and excess fuel is returned to the fuel tank. The fuel gallery outlet (restricted) fitting is installed in the rear of the cylinder head. See Figure 1-21.

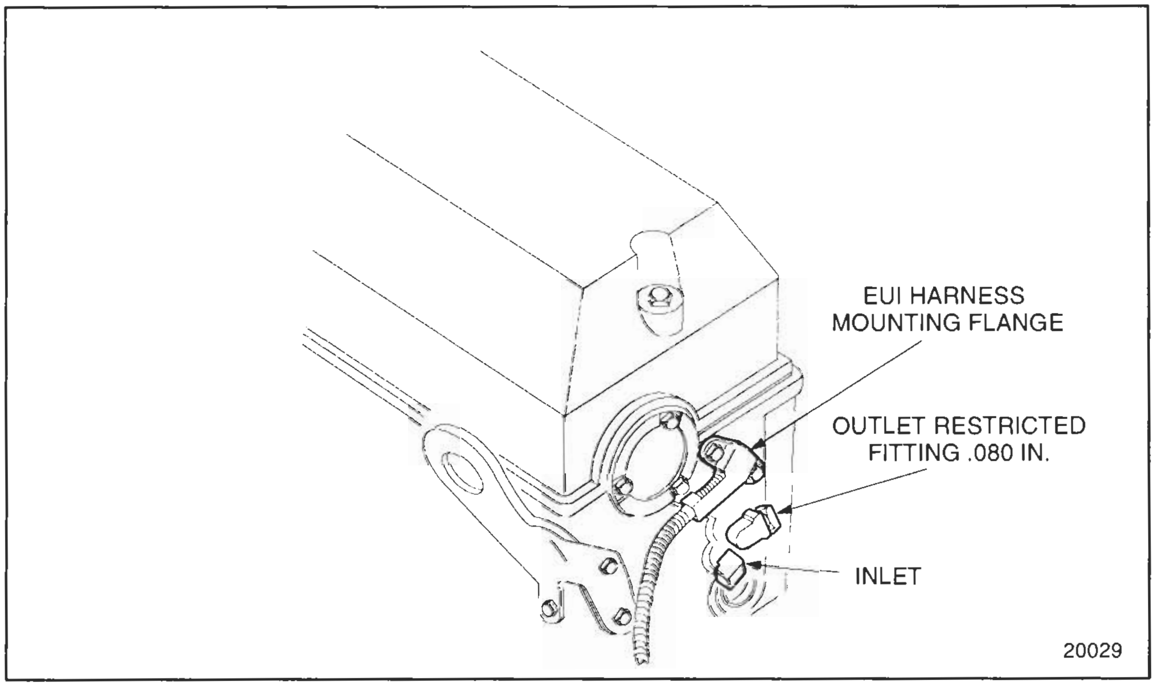


Figure 1–21 Fuel Gallery Inlet and Outlet Fittings

1.2.1 Repair or Replacement of Cylinder Head

To determine if repair is possible or replacement is necessary perform the following procedure. See Figure 1-22.

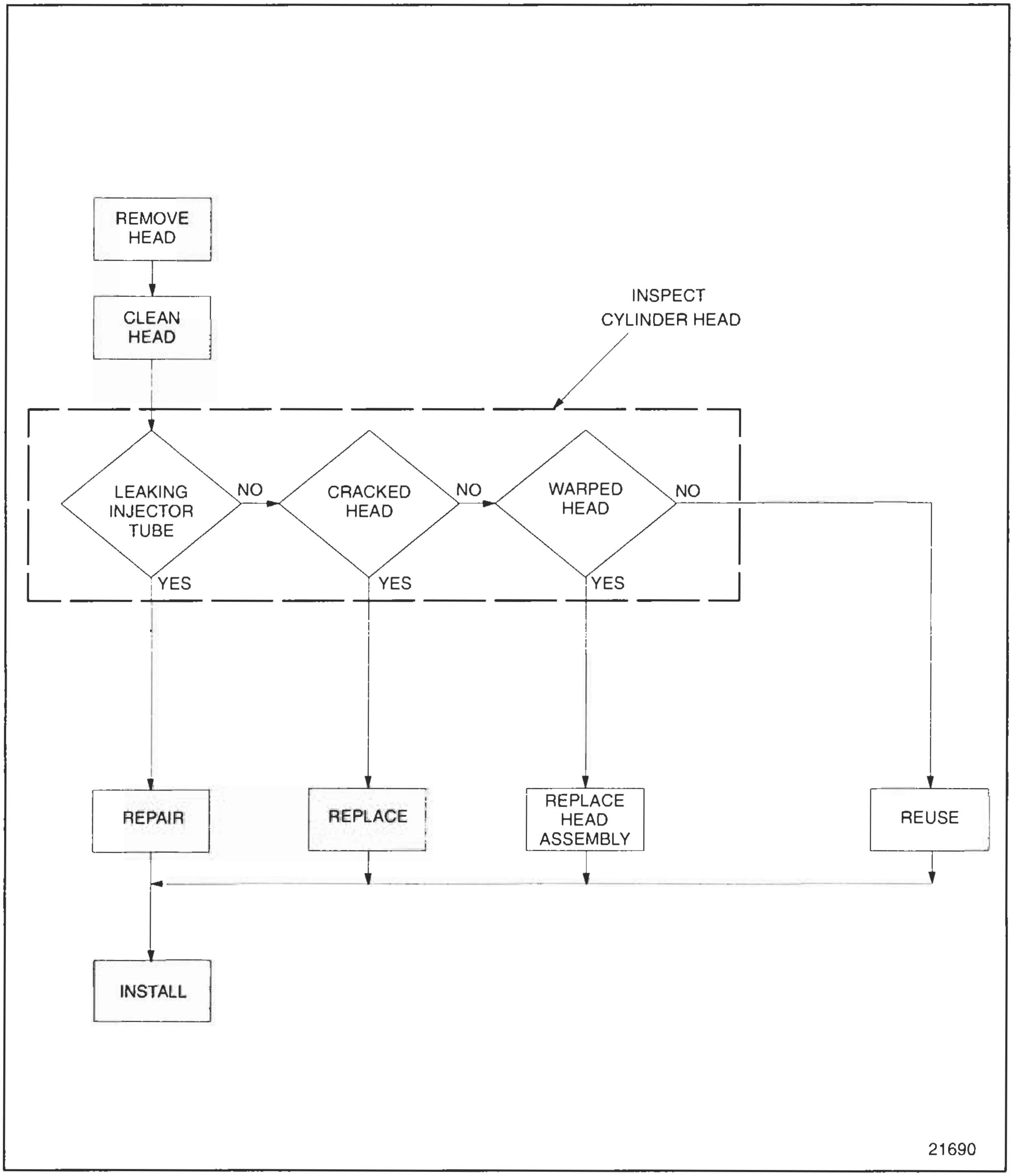


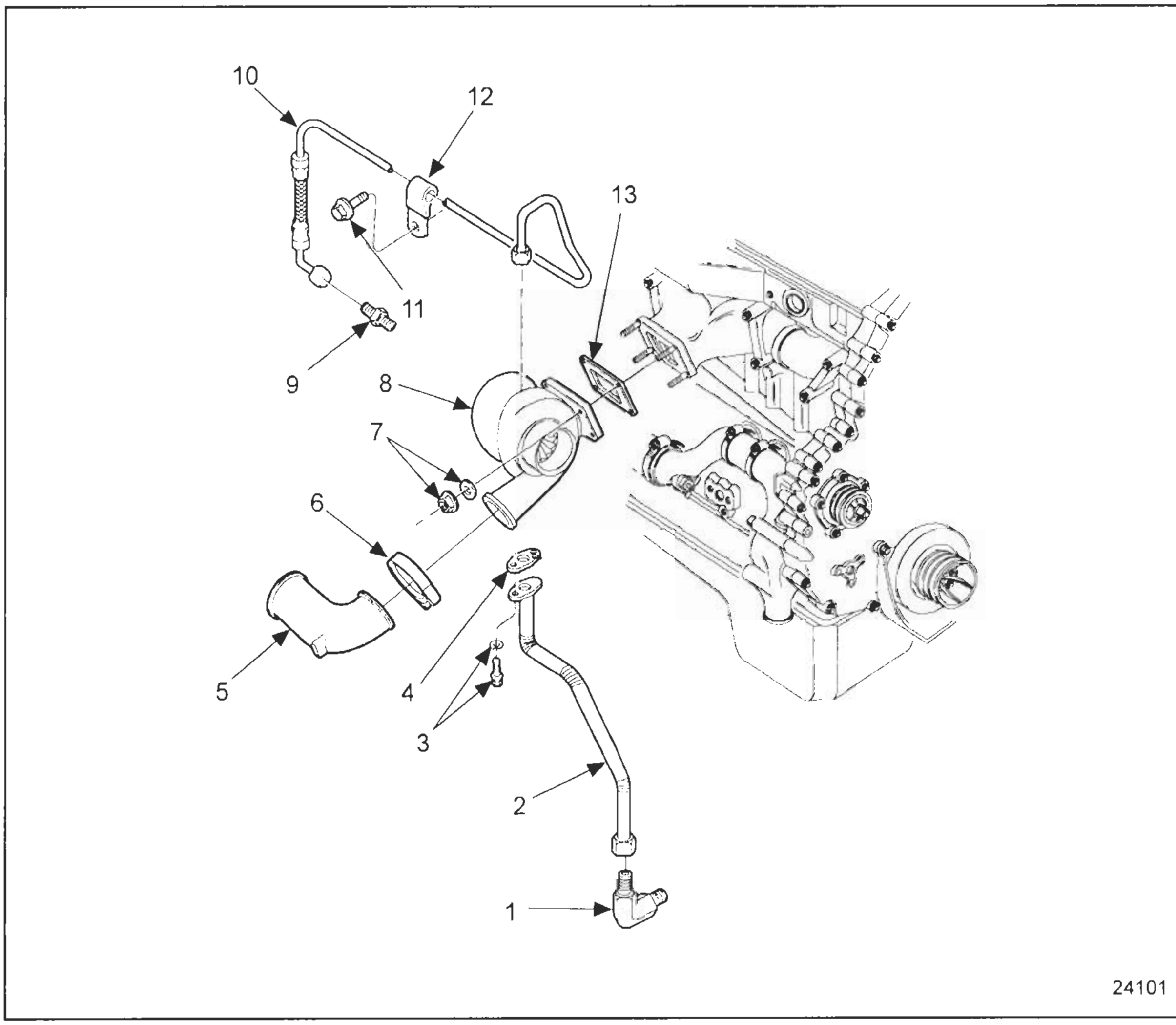
Figure 1-22 Flowchart for Repair or Replacement of Cylinder Head

1.2.2 Removal and Cleaning of Cylinder Head

Because optional and accessory equipment varies with the engine application, this procedure covers only the basic engine. If the engine is equipped with accessories that affect cylinder head removal, note the mounting details of each to assure correct installation at reassembly.

Remove the cylinder head as follows:

1. Drain the cooling system. Refer to section 13.5.4.
2. Disconnect the exhaust pipe at the turbocharger. See Figure 1-23.
3. Remove the air cleaner and charge air cooler ducting from turbocharger and intake manifold. Refer to section 6.2.2 and refer to section 6.5.
4. Disconnect the turbocharger oil supply and drain lines, and remove the turbocharger if necessary. See Figure 1-23.

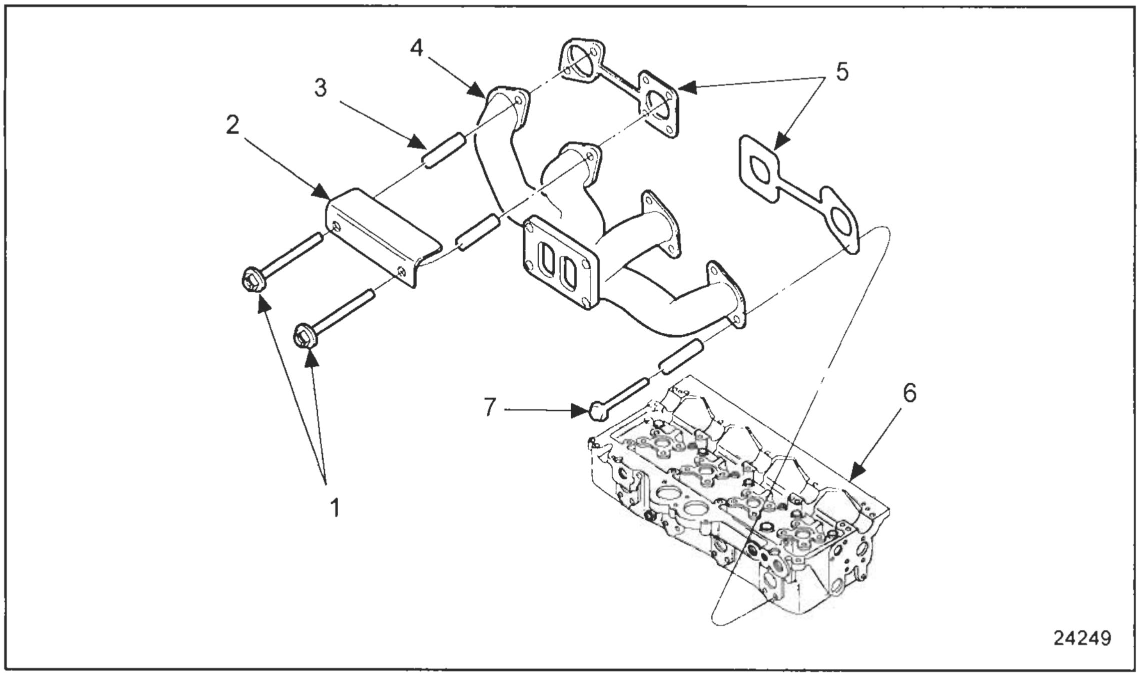


1. Elbow, Oil Drain Tube
2. Tube, Turbo Oil Drain
3. Bolt, Oil Drain Tube Mounting
4. Gasket, Turbo Oil Drain Tube
5. Elbow (Coach Models only)
6. Clamp (Coach Models only)
7. Nut, Turbo Mounting
8. Turbocharger Assembly
9. Connector, Oil Supply Tube (from oil filter adaptor)
10. Tube Assembly, Turbo Oil Supply
11. Bolt, Oil Supply Tube Clip
12. Clip, Oil Supply Tube
13. Gasket, Turbo Exhaust Inlet

Figure 1–23 Turbocharger Oil Lines

5. Seal the turbocharger compressor inlet and discharge with covers or masking tape. Plug the oil supply fitting in the turbocharger housing.

6. Remove the exhaust manifold if necessary. Refer to section 7.2.2. See Figure 1-24.

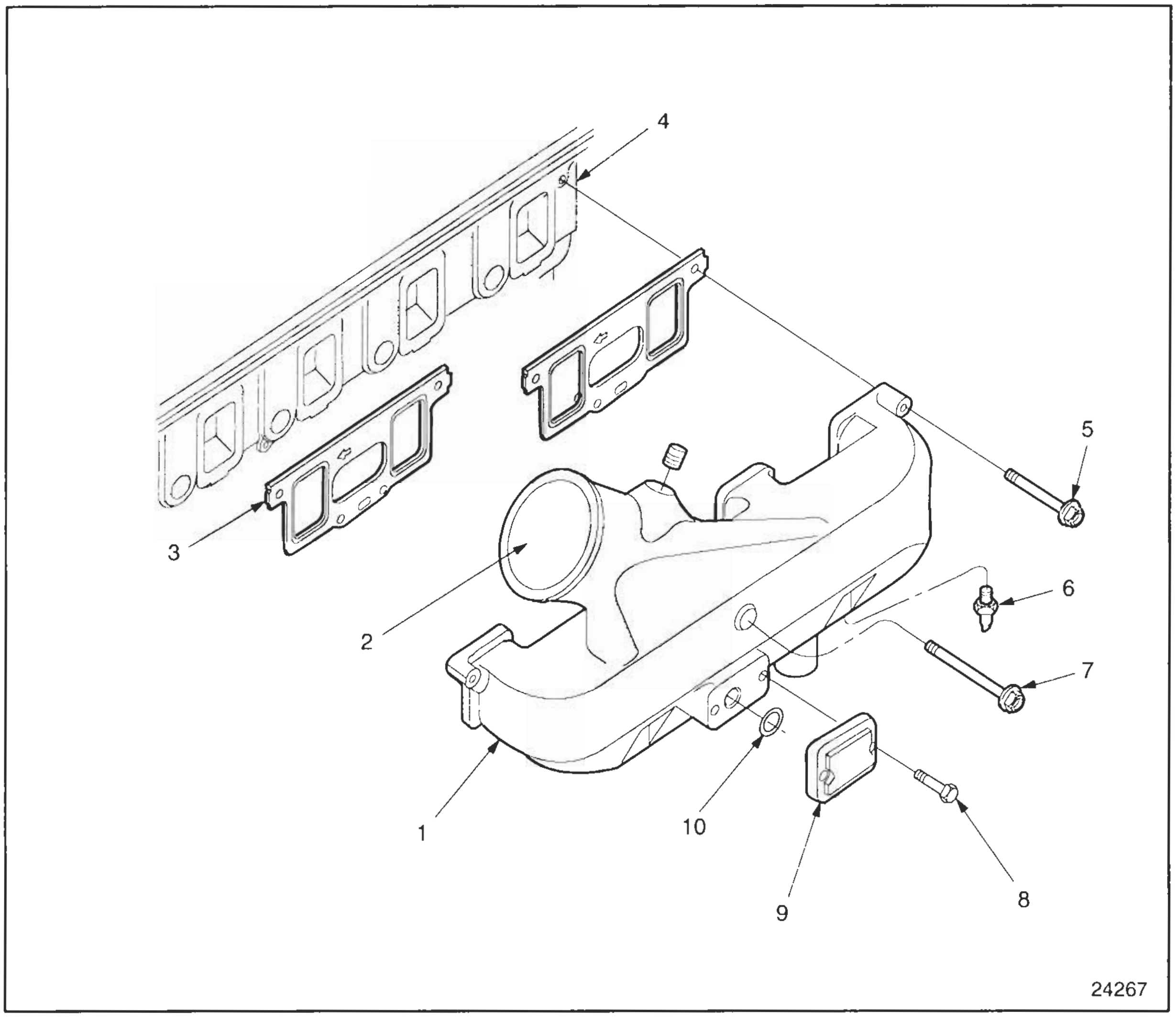


1. Nut
2. Stud
3. Heat Shield
4. Sleeve
5. Exhaust Manifold
6. Gaskets
7. Cylinder Head
8. Bolt

Figure 1-24 Exhaust Manifold

7. Inspect the exhaust manifold. Refer to section 7.2.2.1.

8. Remove and inspect the intake manifold. See Figure 1–25.

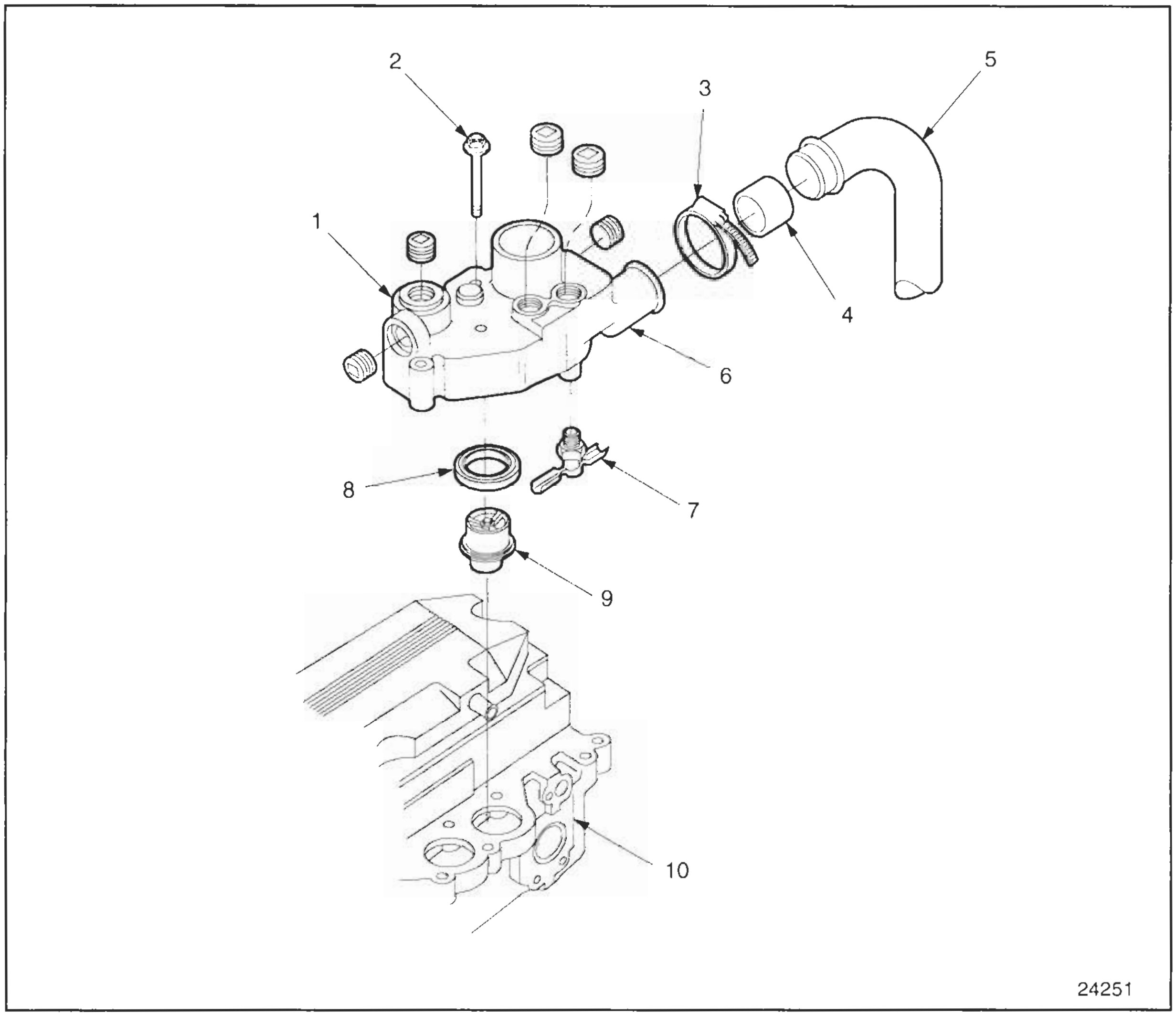


1. Intake Manifold
2. Air Inlet
3. Intake Manifold Gasket (2)
4. Cylinder Head
5. Short Bolt (2)
6. Air Temperature Sensor (DDEC III only)
7. Manifold Bolt (7)
8. Turbo Boost Pressure Sensor Bolt (2)
9. Turbo Boost Pressure Sensor
10. O–ring

Figure 1–25 Intake Manifold and Related Parts

9. Open the drain cock in the bottom of the thermostat housing to allow the coolant in the housing to drain.

10. Disconnect radiator, bypass pipe and hose clamps, and remove the thermostat housing. Refer to section 4.3.2 and see Figure 1-27.



1.	Vent	6.	Thermostat Housing Cover
2.	Thermostat Housing–to–Cylinder Head Bolts (4)	7.	Drain Cock
3.	Hose Clamps (2)	8.	Thermostat Housing Seals (2)
4.	Coolant Hose	9.	Thermostat (2)
5.	Bypass Tube	10.	Cylinder Head

Figure 1–26 Thermostat Housing Removal

11. Remove the valve rocker cover. Refer to section 1.6.2.
12. Disassemble the valve rocker cover. Refer to section 1.6.3.
13. Inspect the valve rocker cover. Refer to section 1.6.3.1.

14. Remove Jacob's Brakes, if equipped. Refer to section 1.29.2.

NOTE:
Using the camshaft gear pilot tool, J 35906, pull the camshaft gear and thrust plate forward in the gear case until there is approximately a 6.35 mm (1/4 in.) gap between the cylinder head and the diamond–shaped camshaft thrust plate seal when removing the cylinder head. See Figure 1–27.

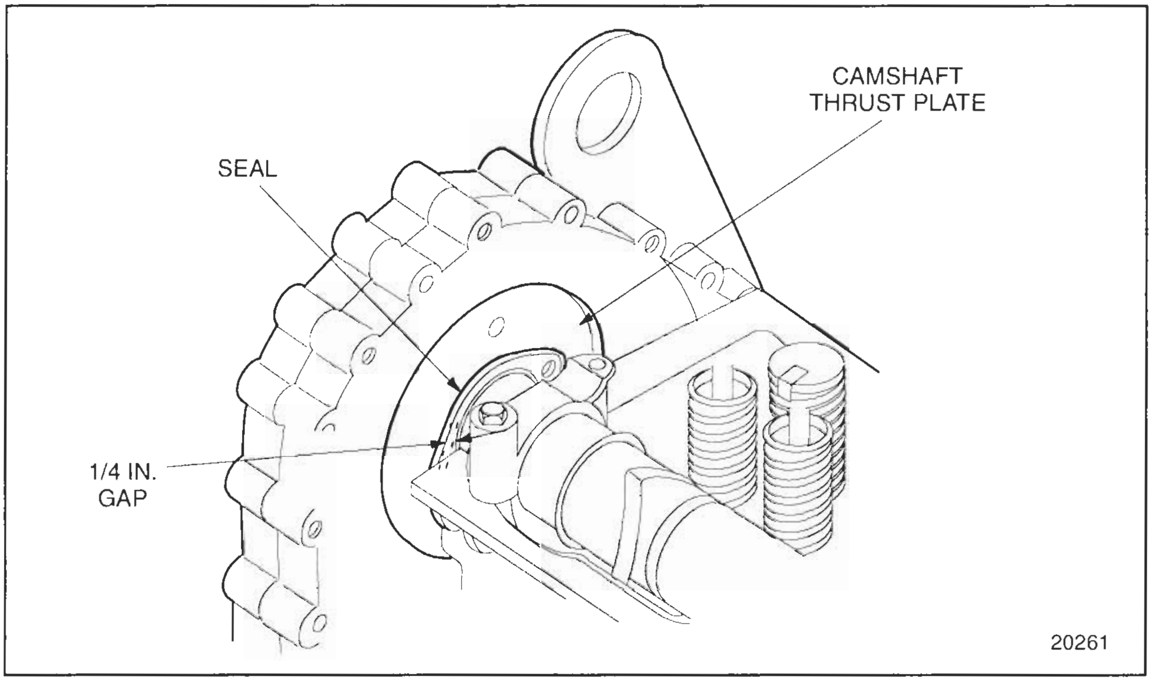


Figure 1–27 Camshaft Thrust Plate

15. Remove the rocker arm assemblies. Refer to section 1.3.2.
16. Inspect the rocker arm assemblies and camshaft lobes.
    Refer to section 1.3.2.1.
17. Remove the camshaft. Refer to section 1.22.2.

NOTE:
Fuel must be removed from the cylinder head fuel galleries prior to removing the injectors.

18. Disconnect the fuel inlet and outlet lines at the rear of the cylinder head. See Figure 1–28.

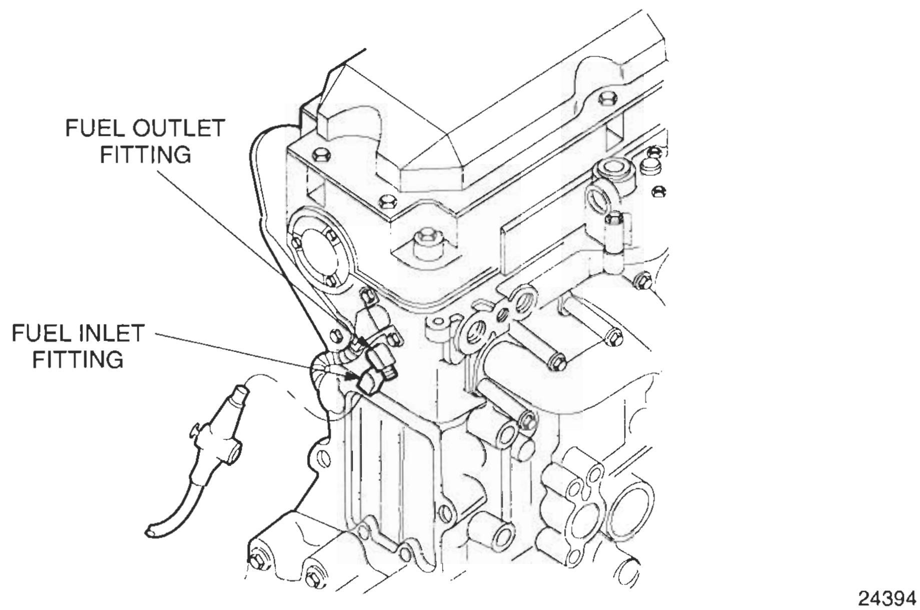


Figure 1–28 Removing Fuel from Cylinder Head Internal Passages

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

19. Blow low pressure compressed air into the inlet fitting for 20 to 30 seconds or until all of the fuel is purged from the cylinder head.
20. Disconnect the injector wire harness at each injector. Refer to section 2.2.2.
21. Remove the harness mounting flange from the rear of the cylinder head and carefully remove the harness from the head by pulling the harness through the hole in the cylinder head. See Figure 1–21.

NOTICE:

To avoid possible damage to the injector spray tips, remove the injectors before lifting the head from the block. If the injectors are not removed, handle the head carefully when it is off the block and support the head firedeck on wooden blocks.

22. Remove the fuel injectors. Refer to section 2.2.2.

23. Remove the gearcase stabilizer bracket at the right front corner of the head.
24. Remove the head bolts and install the cylinder head lift bracket, J 35641–A, using the bolt hole at the inboard center, No. 3 cam cap and two tapped Jacob's Brake bolt holes. See Figure 1–29.

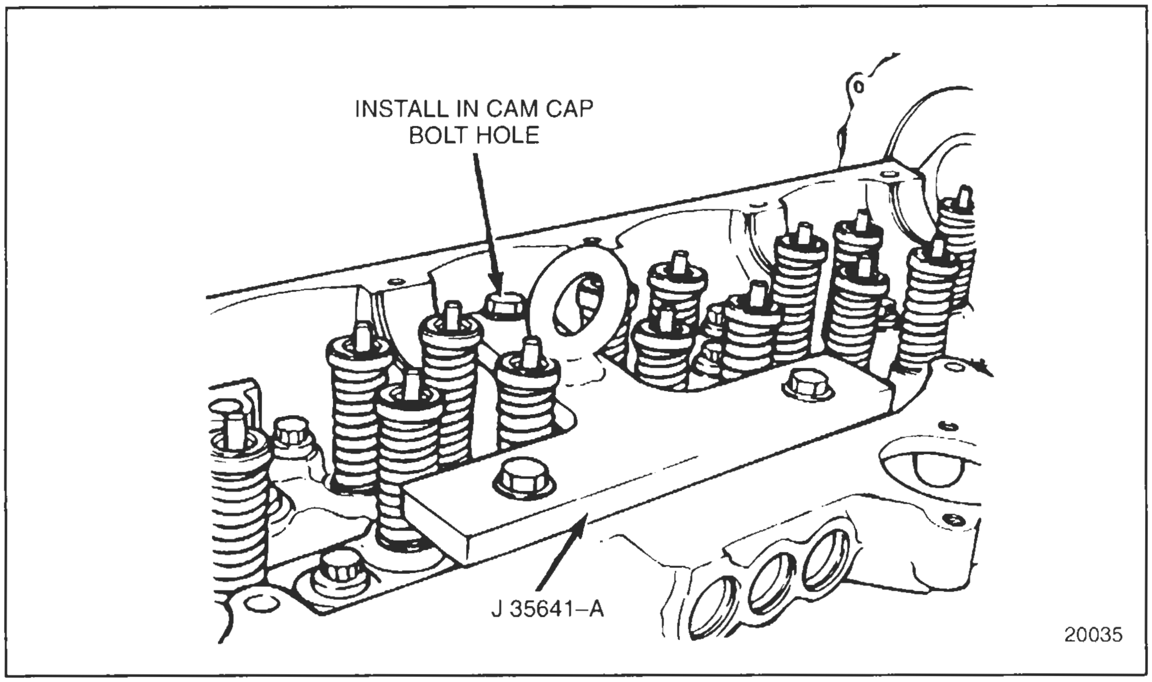


Figure 1–29 Cylinder Head Lift Bracket Installation

25. Attach a suitable lifting hook to the eyelet in the lift bracket, and lift the cylinder head off the engine. See Figure 1-30.

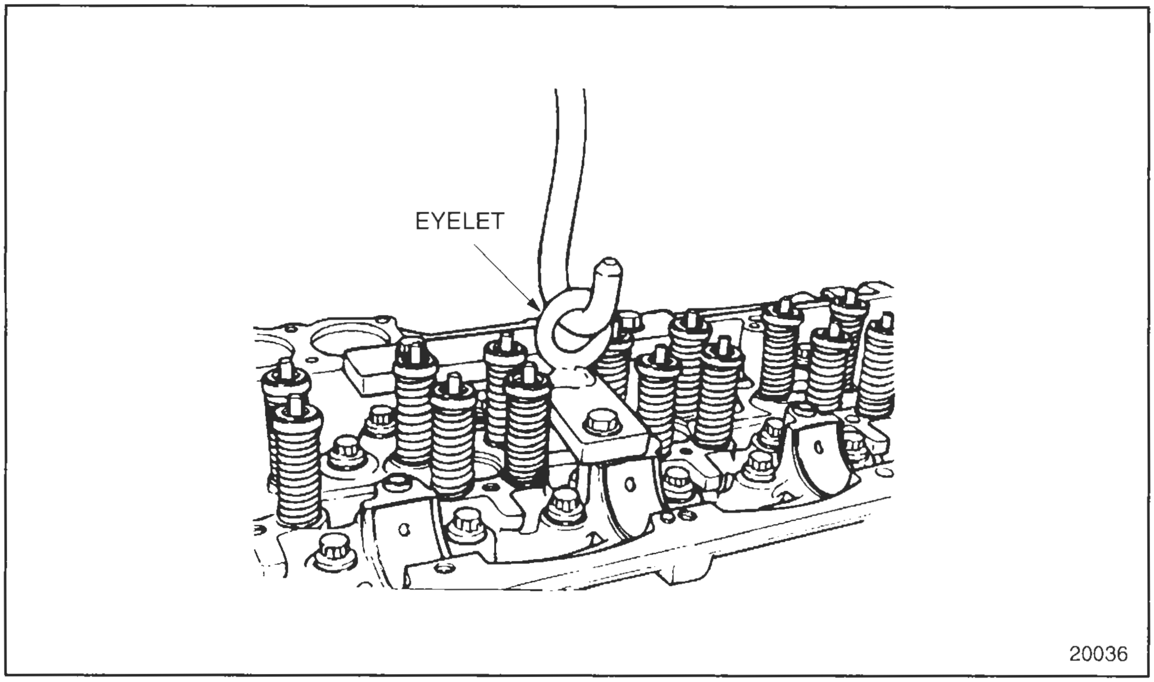


Figure 1-30 Cylinder Head Removal

26. Drain the engine lubricating oil to remove any coolant that may have drained into the oil pan when the water jacket was opened. Remove any coolant from the cylinder bores.

Clean the cylinder head as follows:

1. Keep parts segregated according to original position to assure proper reassembly, if parts are to be reused.
2. Remove all threaded plugs.
3. Steam clean the cylinder head once it has been stripped.

4. If coolant passages are heavily coated with scale, remove the injector tubes and cup plugs and clean the head in a descaling bath, as described under "Removal of Engine from the Vehicle and Disassembly". Refer to section 1.1.2.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

5. Clean the camshaft and camshaft bearings, valves, springs, valve rotators and rocker arm shafts in fuel oil and blow dry with compressed air.

6. Refer to section 1.3.3 for cleaning of rocker arm and roller follower assemblies.

1.2.3 Inspection of Cylinder Head

The following steps must be performed before inspecting the cylinder head:

1. Replace the plugs removed for cleaning. If the old plugs are reused, coat the plugs with Loctite; pipe sealant, J 26558-92: with Teflon; or equivalent.

NOTE:
If both front fuel galley plugs have been removed, it will be necessary to replace both plugs.

2. If injector tubes have been removed, install new injector tubes. Refer to section 2.3.5.
3. Install new cup plugs using a good grade non-hardening sealant such as Loctite 620 or equivalent.

Perform the following tests for cylinder head inspection.

- ❑ Pressure test, refer to section 1.2.3.1
- ❑ Firedeck straightness test, refer to section 1.2.3.2

1.2.3.1 Pressure Test

Perform the following steps to pressure test the cylinder head:

1. Install the test strips (part of cylinder block pressure test kit,) to the firedeck on the cylinder head. See Figure 1-31.

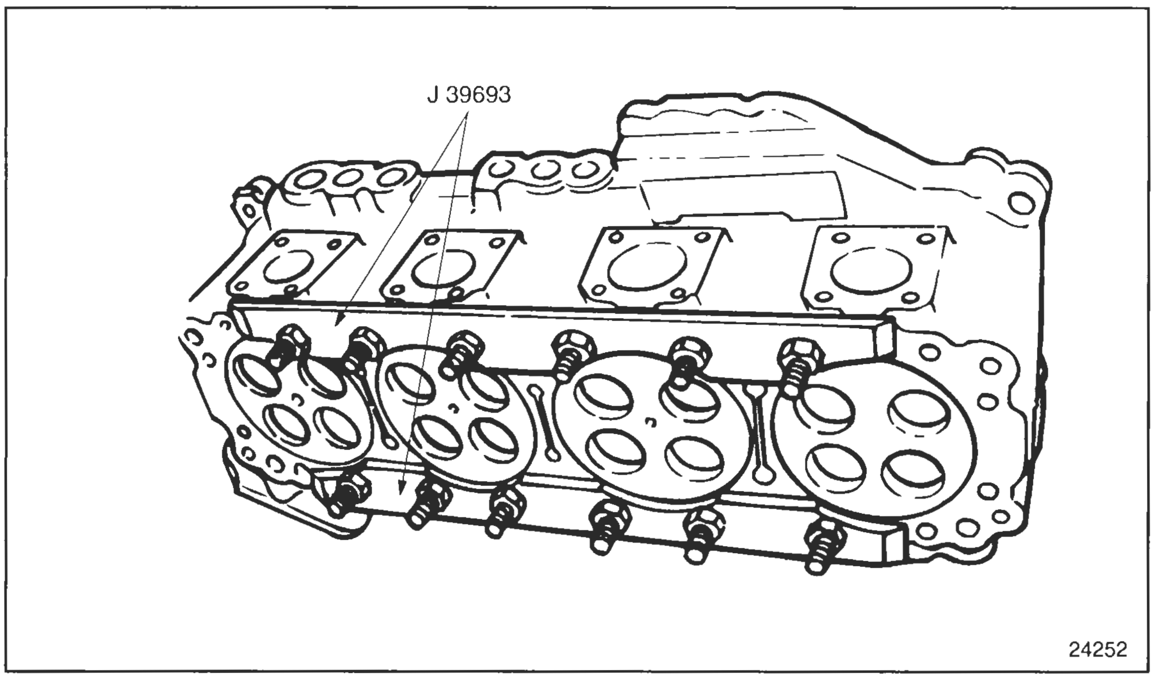


Figure 1-31 Cylinder Head Pressure Test Equipment Installation

2. Insert the cylinder head bolts through the cylinder head and test strips. Attach and tighten the nuts (supplied in J 36223-D) to 14 N·m (10 lb·ft).

3. Install the thermostat opening cover plate, J 35984-2 and gasket to the cylinder head using the bolts provided with the cover plate. See Figure 1-32.

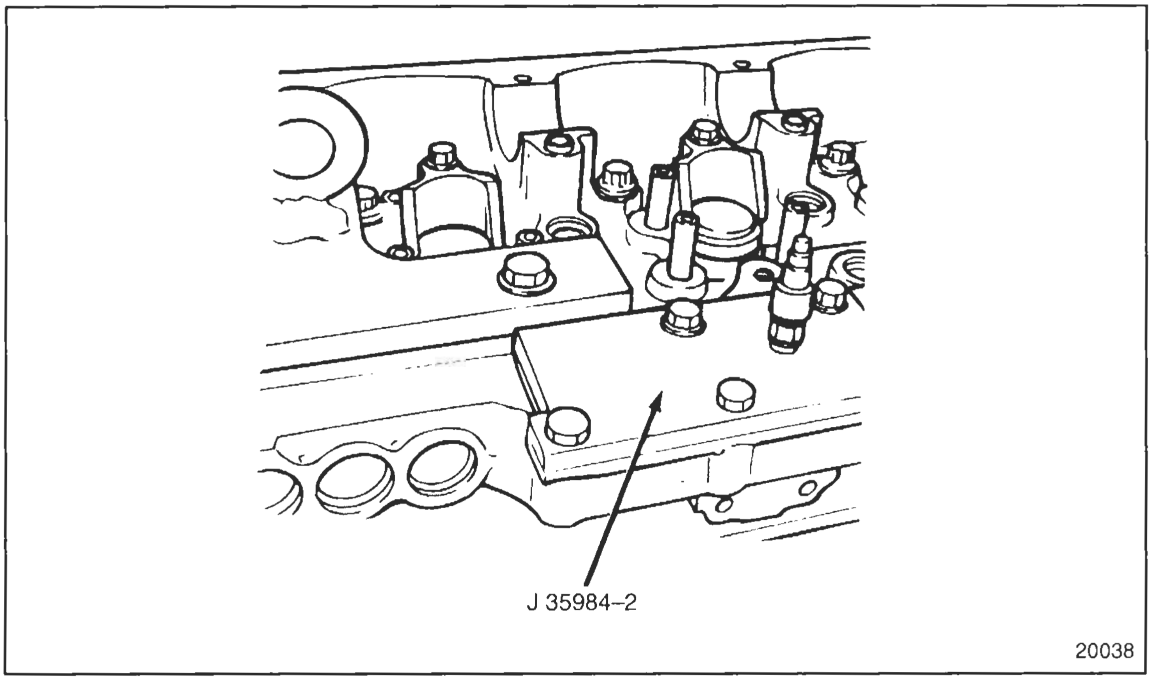


Figure 1-32 Thermostat Opening Cover Plate Installation

4. Install dummy fuel injectors, J 35984-1, to the injector bores to assure proper seating of the fuel injector tubes. See Figure 1-33.

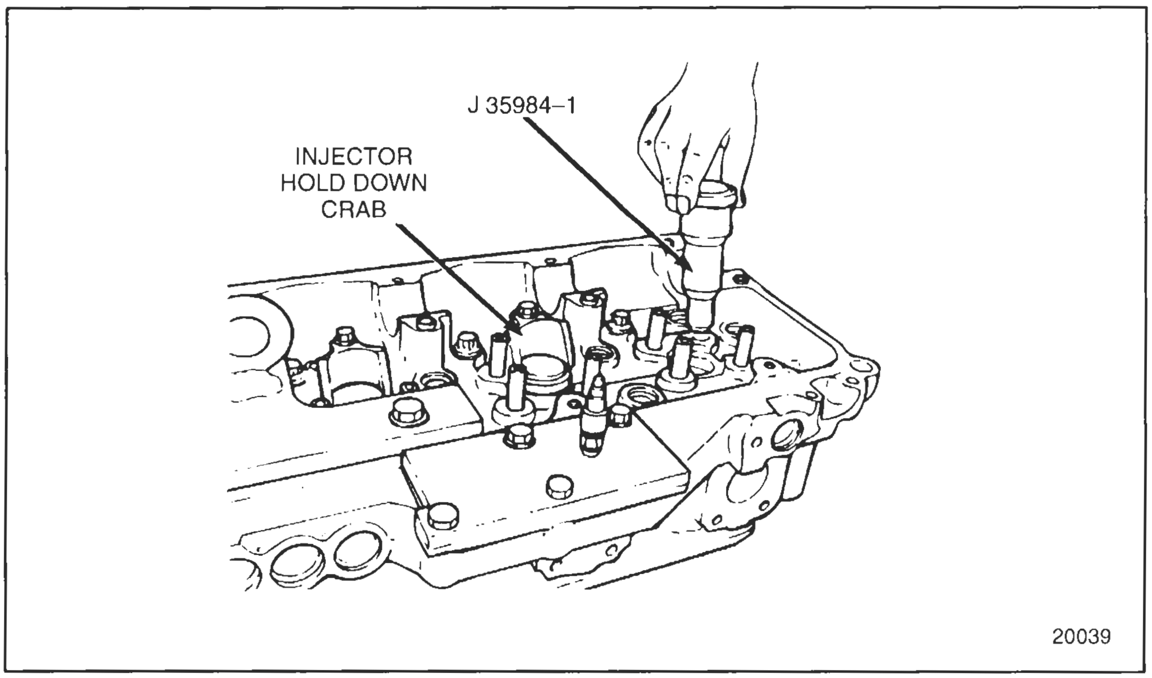


Figure 1-33 Test Injector Installation

5. Install the fuel injector crabs and hold-down bolts. Tighten the bolts to 58-66 N·m (43-49 lb·ft) torque.
6. Attach an air hose to the fitting on the thermostat opening cover plate.
7. Apply 207 kPa (30 lb/in.^{2}) air pressure to the cylinder head and immerse the head in a water bath heated to 82-93°C (180-200°F).
8. Leave the head in the bath for at least 20 minutes to heat thoroughly, while watching for bubbles indicating a crack or leak. Injector tube leaks can be stopped by replacing tubes.
   [a] If an injector tube leaks, replace tube(s). Refer to section 2.3.2 for removal and refer to section 2.3.5 for replacement.
   [b] If a cracked head is detected, replace the head. Refer to section 1.2.1.

1.2.3.2 Inspection and Rework for Firedeck Straightness

The large mass and length of the head casting may contain longitudinal warp after it is unbolted and removed from the engine block. At the time of factory manufacture, the longitudinal warp is normalized by fixturing and clamping the casting during machining. The casting is fixtured and clamped from its locating surfaces (datums). When unclamped, the head casting resumes its original shaped until it is bolted and tightened to the engine block.

Inspect the bottom (firedeck) of the cylinder head for straightness as follows:

1. Use a heavy, accurate straight-edge and feeler gages to check for transverse and longitudinal warpage. See Figure 1-34.

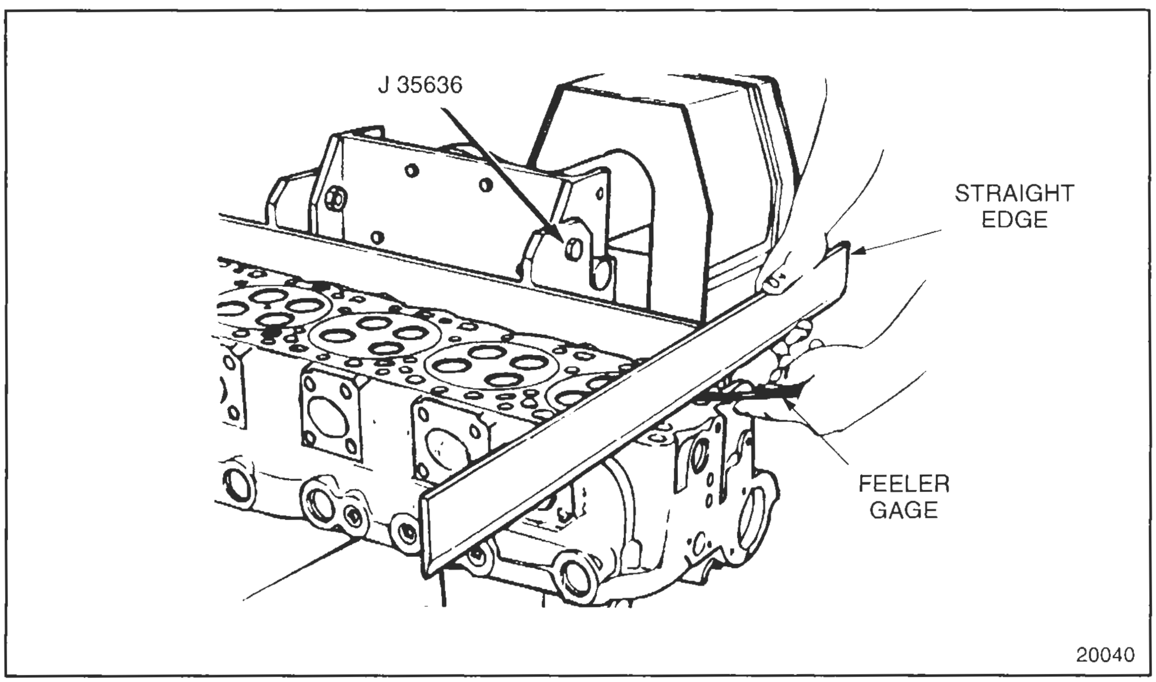


Figure 1-34 Checking Firedeck Straightness

2. Also, check for longitudinal warpage in five places and transverse warpage in 8 places, indicated as A through H in the next illustration. See Figure 1-35.

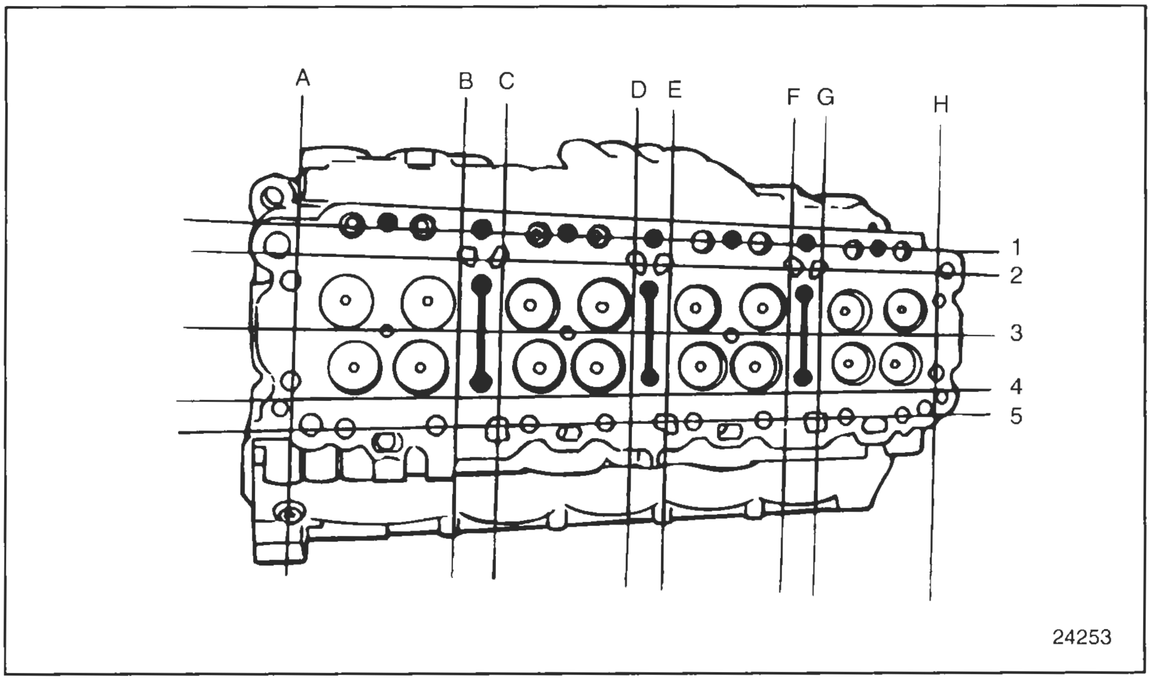


Figure 1–35 Cylinder Head Measurement Locations

3. The natural warp contained in the casting must be considered when inspecting firedeck straightness with the head unbolted and unclamped. Natural warpage is not a cause for correction. The firedeck (unclamped) must be straight within 0.120 mm (.005 in.) front-to-rear and 0.076 mm (.003 in.) side-to-side.

   [a] If the cylinder head flatness is outside of the specifications, Detroit Diesel Corporation **does not** recommend firedeck resurfacing.

1.2.3.3 Head Bolt Counterbore Inspection and Rework

To assure clean and non-brinnelled cylinder head bolt counterbores, use tool J 38189 to resurface the head bolt washer area.

The procedure and steps for proper use of the tool are as follows:

NOTICE:
There must be no space between the bottom of the cylinder head and the table top to properly resurface the counterbores.

1. Place the cylinder head on a solid flat surface (preferably a steel table top) that completely covers the bottom of head.

NOTICE:
Proper use of the J 38189 is important. Failure to use J 38189 properly, may result in an incorrect counterbore depth.

2. Protect the valve springs and injector counterbore to keep any loose metal shavings from getting into valve springs and counterbore during cutting operation.
3. With cylinder head on a flat surface using the 1/8 in. hex wrench supplied with tool, loosen the stop collar and cutter to permit sliding on pilot.
4. Starting at the front of the cylinder head, place the pilot of the cutter into a cylinder head bolt hole until the pilot contacts the flat surface beneath the cylinder head.
5. Allow the cutter to contact the counterbore surface. Lock the stop collar while against the cutter. The cutter now will resurface the counterbore 0.5 mm (.020 in).
6. Remove the tool and place a 0.5 mm (.020 in.) feeler gauge between the cutter and the locked stop collar.
7. With feeler gauge in place, lock the set screw of the cutter, then remove the feeler gauge and loosen the set screw on the stop collar and slide it down tight against the cutter and retighten.

Perform the following steps to resurface the counterbore 0.5 mm (.020 in.):

1. Using a drill motor with a 1/2 in. chuck and a **maximum** of 450 r/min and a suitable cutting oil to prolong the life of the cutter and to lubricate the pilot turning in bolt hole.
2. Apply a moderate pressure on the drill motor, continue cutting operation until pilot bottoms on flat surface and then do not stop drill motor until after being lifted from cutting surface. This is to eliminate surface marks.

NOTE:
The J 38189 tool pilot has a shoulder stop that will not allow the cutter to remove material in excess of the Detroit Diesel Corporation specifications.

3. If some of the bolt holes do not clean up completely, continue resurfacing remaining holes, repeating the operation in 0.5 mm (.005 in.) increments. This will clean up any holes that may not have cleaned up completely during the first cut.
4. After all counterbores have been resurfaced, remove any loose cutting chips.
5. Steam clean the complete cylinder head.
6. After steam cleaning, inspect the cylinder head for any remaining chips.
7. Reinstall the cylinder head assembly, using 26 of the new ground head bolt washers.

1.2.4 Assembly of Cylinder Head

Perform the following steps for cylinder head assembly:

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

NOTICE:

If the cylinder head is to be replaced, the new head must be thoroughly cleaned before installation to remove all rust preventive compound, especially from the fuel and oil galleries. This can be done by immersion in a bath of fuel oil or mineral–spirits–based solvent and scrubbing out all openings with a soft bristle brush. When clean, blow the head dry with compressed air.

1. Install new precoated pipe plugs or coat the used plugs with pipe sealant with Teflon, J 26558-92, or equivalent, and tighten them as listed in Table 7 which can be found in the "General Information" section at the beginning of the manual.
2. Install all of the required cup plugs using a good grade of non–hardening sealant, such as Loctite 620 or equivalent, on the cup plugs. Use cup plug installation tool set, J 35653.
3. Be sure that all cup and pipe plugs on the front face of the cylinder head are flush or below the surface.
4. Install valve guides and seats, valves, valve stem seals, valve springs and rotators. Refer to section 1.4.

1.2.5 Installation of Cylinder Head

Perform the following steps for cylinder head installation:

1. Be sure piston domes and the cylinder head and cylinder block firedeck surfaces are clean and free of foreign matter. Inspect the head bolt holes in both block and head for the presence of oil, water, dirt, or damaged threads, and clean or retap as necessary.
2. Position the head gasket on the block and install cylinder head guide studs, J 35784, at front and rear of the block. See Figure 1–36.

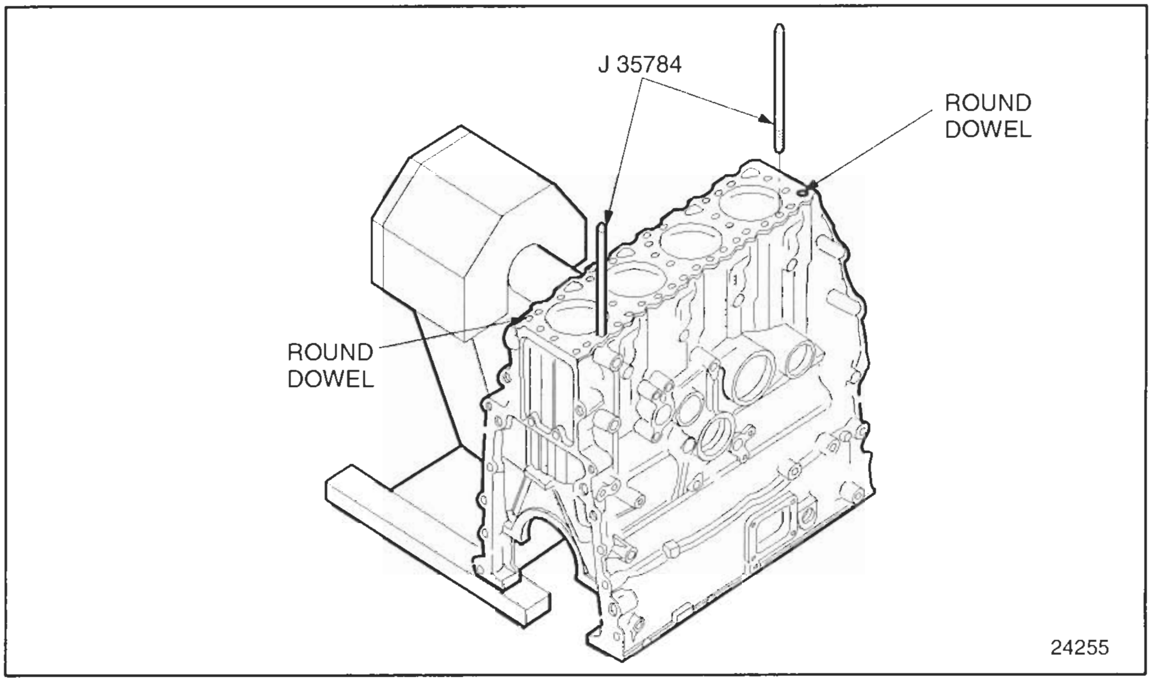


Figure 1–36 Cylinder Head Guide Studs

3. Lift the head into position with lift bracket, J 35641–A. See Figure 1–30. Lower it into place over the guide studs, J 35784, until it seats on the block deck dowels. See Figure 1–36.
4. Remove the guide studs.
5. Install the head bolts with special hardened washers, lubricating the threads and bolt–head contact areas with a small amount of International Compound No. 2, or equivalent.

6. Tighten the head bolts to 250–285 N·m (185–210 lb·ft) in the sequence. See Figure 1–37.

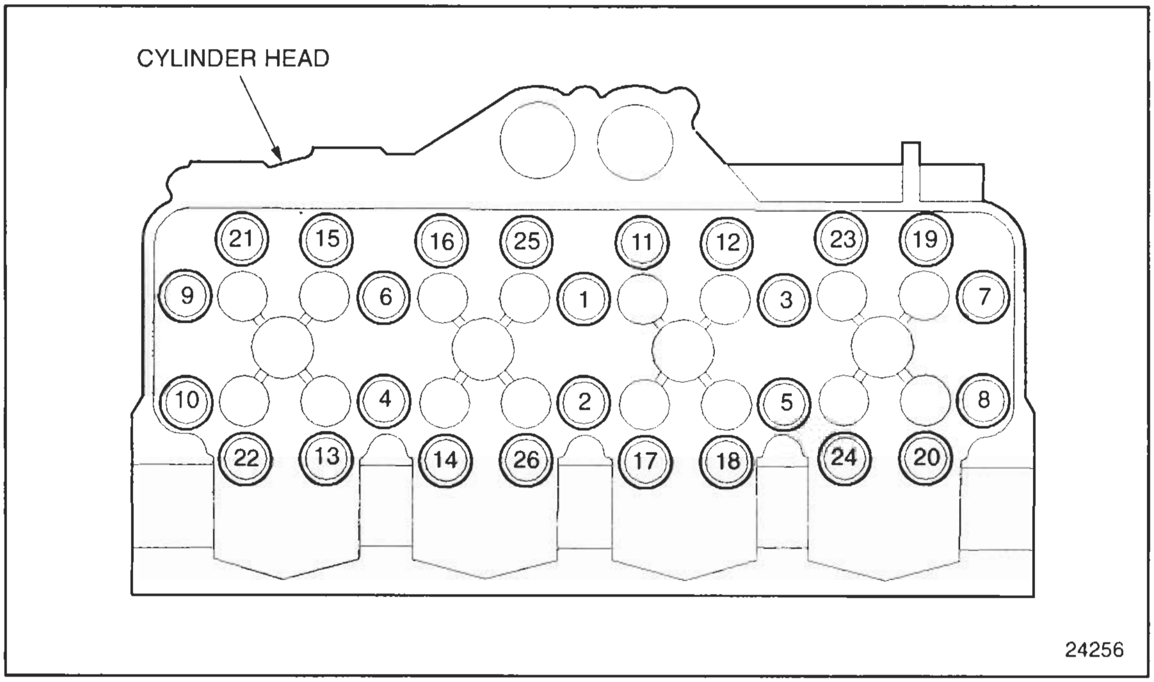


Figure 1–37 Cylinder Head Bolt Tightening Sequence

NOTICE:
Failure to repeat the cylinder head bolt torque tightening sequence can result in some head bolts may lose their torque when others are tightened resulting in insufficient clamp load.

7. Repeat the torque sequence to verify all of the head bolts are torqued to specification.

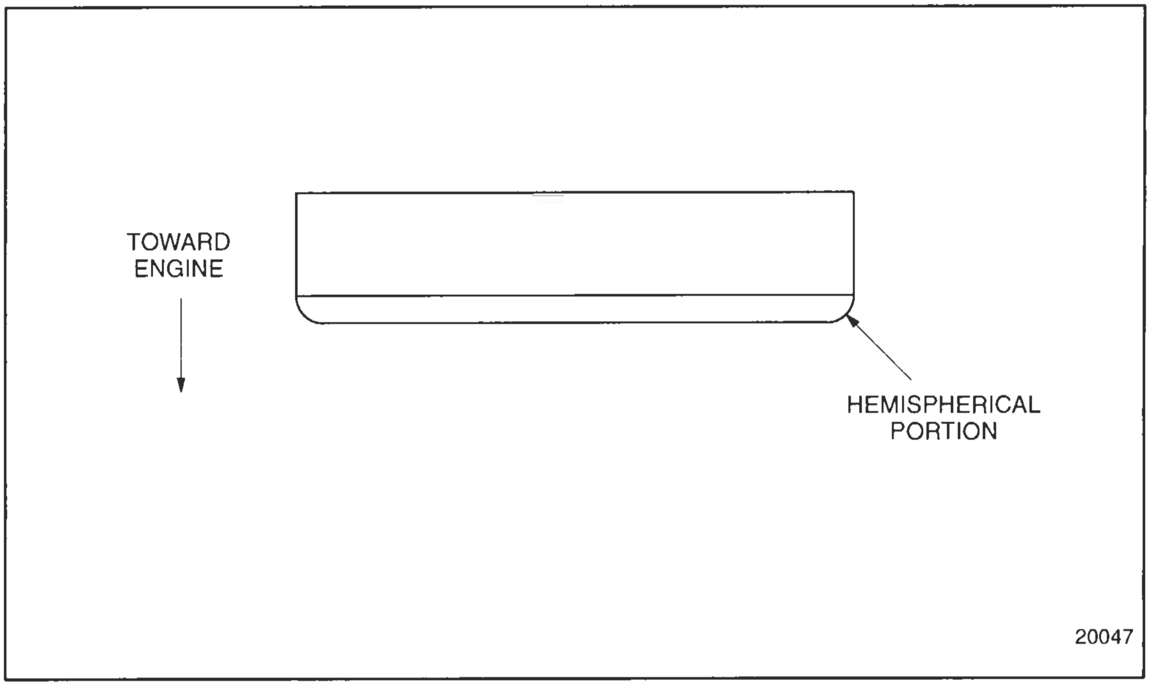


Figure 1–38 Injector Hold–Down Crab Washer Installation

NOTE:
If a cylinder head other than the one removed from the engine, or if a resurfaced cylinder head is being installed, the three nuts retaining the adjustable idler gear must be loosened before installing and torquing the camshaft drive gear retaining bolt.

8. Visually inspect each injector hole tube to ensure they are clean. Install the fuel injectors. Refer to section 2.2.5. Be sure the injector hold–down crabs are clear of the valve and injector springs.

NOTICE:
The hemispherical portion of the injector hold–down crab washers must be installed facing the crab (pointing down) in order to prevent damage to the washers. See Figure 1–38.

9. Install the clamp bolts with hemispherical washers, tightening to 58–66 N·m(43–49 lb·ft) torque.
10. Install the camshaft. Refer to section 1.22.5.

NOTICE:
The camshaft drive gear–to–adjustable idler gear lash must be measured/adjusted before the rocker arm shaft assemblies are installed.

11. Measure/adjust the camshaft drive gear–to–adjustable idler gear lash. Refer to section 1.23.
12. Install the rocker arm shaft assemblies. Refer to section 1.3.3.
13. Install Jacob's Brake assemblies (if equipped). Refer to section 1.29.3.
14. Feed the injector harness wires through the opening at the rear of the cylinder head. Secure the harness mounting flange to the cylinder head by tightening the bolts to 10–15 N·m (7–11 lb·ft) torque.
15. Connect the injector harness wires to their respective injectors. Refer to section 2.2.6.
16. Install the gear case stabilizer bracket at the right front corner of the head. Tighten the stabilizer to gear case bolt first and then the two bolts to the head. Tighten the three bolts to 58–73 N·m (43–54 lb·ft).
17. Install the thermostats and seals to the thermostat housing. Refer to section 4.3.4.
18. Clean the coolant outlet surfaces of the head and thermostat housing.
19. With the thermostats seated in the housing counterbores, install the housing to the cylinder head, tightening the housing bolts to 58–73 N·m (43–54 lb·ft) torque. Connect the radiator and bypass hose couplings and vent line.

20. Remove all traces of the old gasket from the cylinder head and intake manifold joint surfaces. Install the intake manifold with new gaskets. Refer to section 6.3.3. See Figure 1–39.

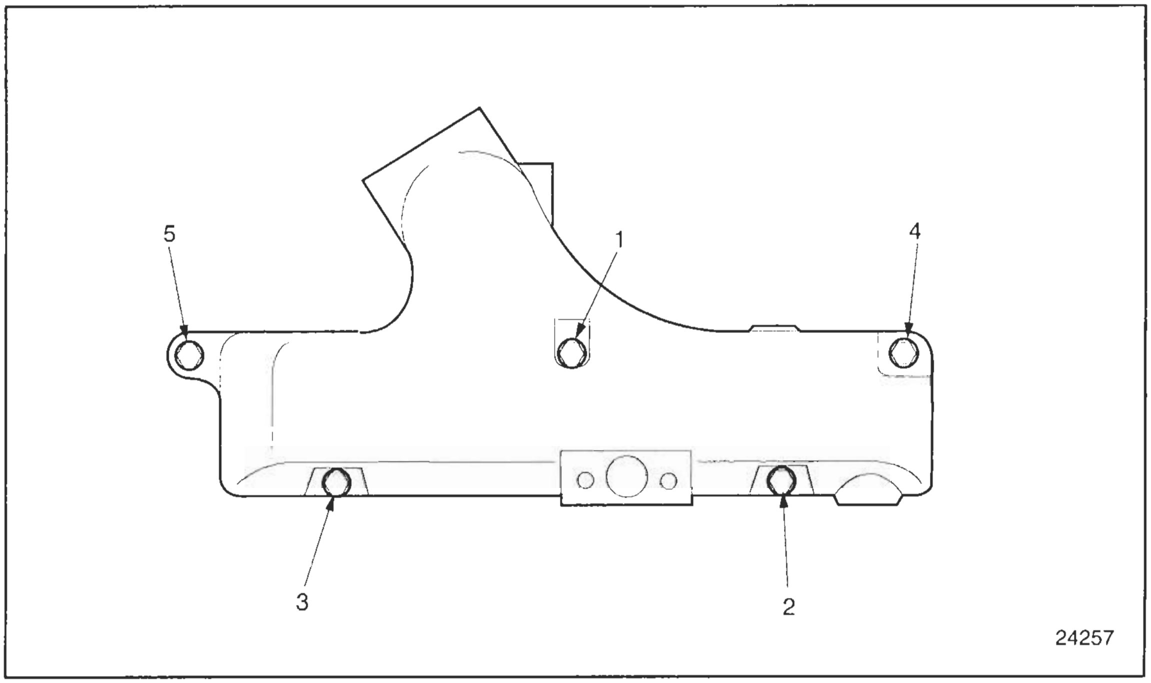


Figure 1–39 Intake Manifold Bolt Tightening Sequence

21. Clean the intake manifold and turbocharger joint surfaces and install the turbocharger with a new gasket. Refer to section 6.4.5.
22. Fill and vent the cooling system. Refer to section 13.5.4. Fill the engine lubrication system. Refer to section 13.5.1.
23. Connect the exhaust and air–to–air cooler air ducting and install the air cleaner, per OEM guidelines.
24. Install any other components that were removed and, if required, fill with the proper fluid, as recommended.
25. Start the engine and check for fuel, coolant or oil leaks. Keep the engine running while you check.

1.3 VALVE AND INJECTOR OPERATING MECHANISM

The valve and injector operating mechanism is located entirely in the cylinder head.

The Series 50 Engines overhead camshaft design eliminates the need for push rods. Separate camshaft followers are needed, since the rocker arms incorporate follower rollers riding directly on the camshaft lobes, transmitting camshaft motion to the valves and injectors. See Figure 1–40.

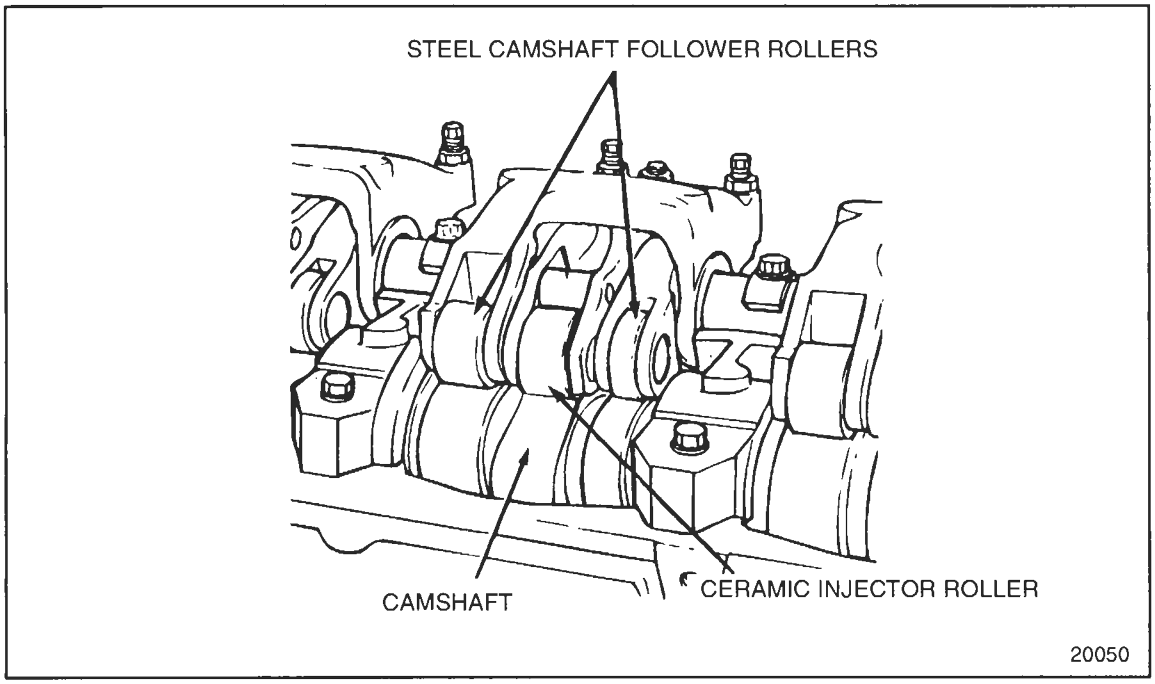


Figure 1–40 Camshaft and Related Parts

Each of the three rocker arm assemblies contain bushings where the rocker arms are supported on the rocker arm shafts. These bushings are not serviced separately. Each intake rocker arm assembly operates two intake or valves in each cylinder. Each exhaust rocker arm assembly operates two exhaust valves in each cylinder. In each set of three rocker arm assemblies, the exhaust rocker assembly is the widest, straddling the intake and fuel injector rockers. The center rocker operates the injector follower. See Figure 1–41.

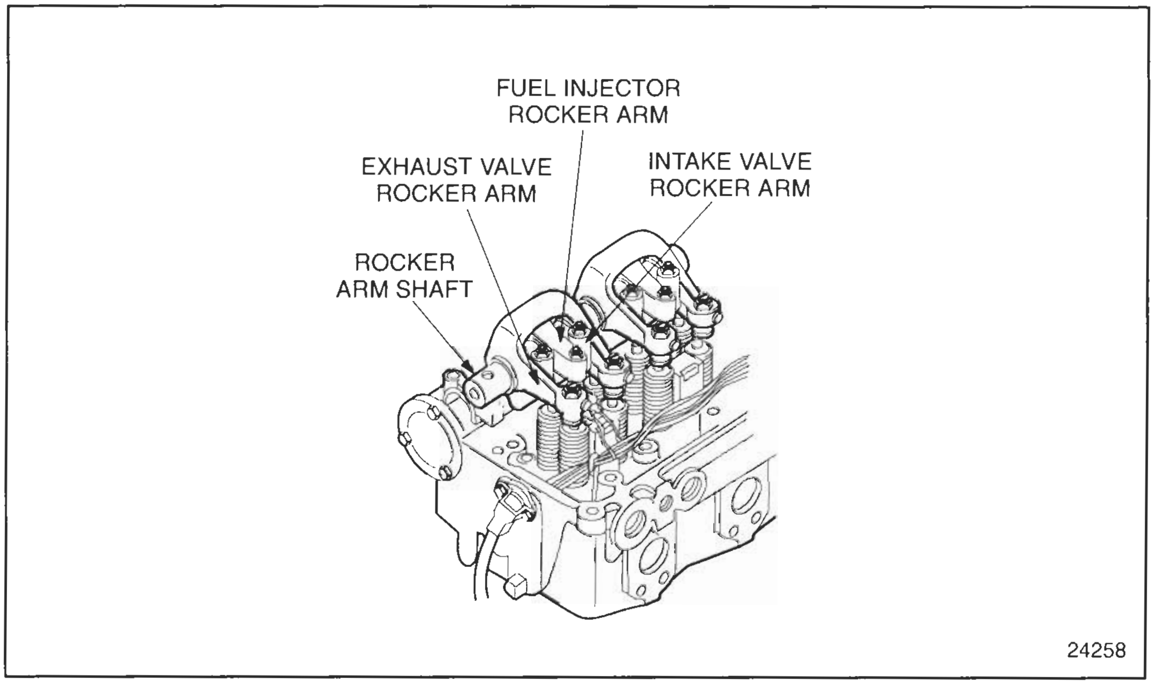
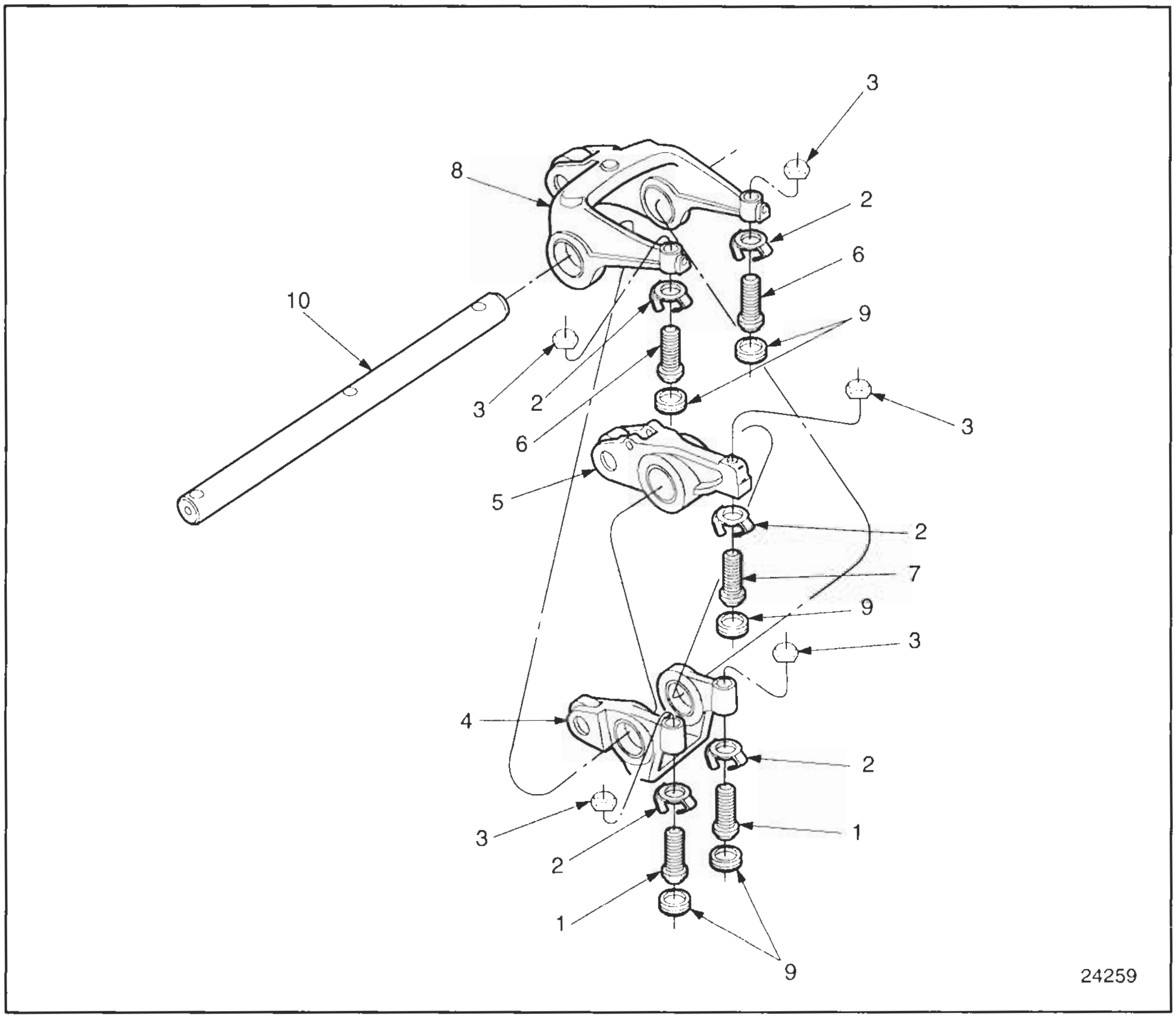


Figure 1–41 Rocker Arm Identification

The fuel rocker arm assembly is located between the intake and exhaust rocker arm assemblies and has a single, bushing (not serviced separately). A rocker arm shaft carries three sets of rocker arm assemblies, and is mounted in seats machined into the camshaft bearing caps. See Figure 1-42.



1. Intake Valve Adjusting Screw
2. Clip
3. Locknut
4. Intake Rocker Arm Assembly
5. Fuel Injector Rocker Arm Assembly
6. Exhaust Valve Adjusting Screw
7. Fuel Injector Adjusting Screw
8. Exhaust Rocker Arm Assembly
9. Valve Button
10. Rocker Arm Shaft

Figure 1-42 Rocker Arm and Related Parts

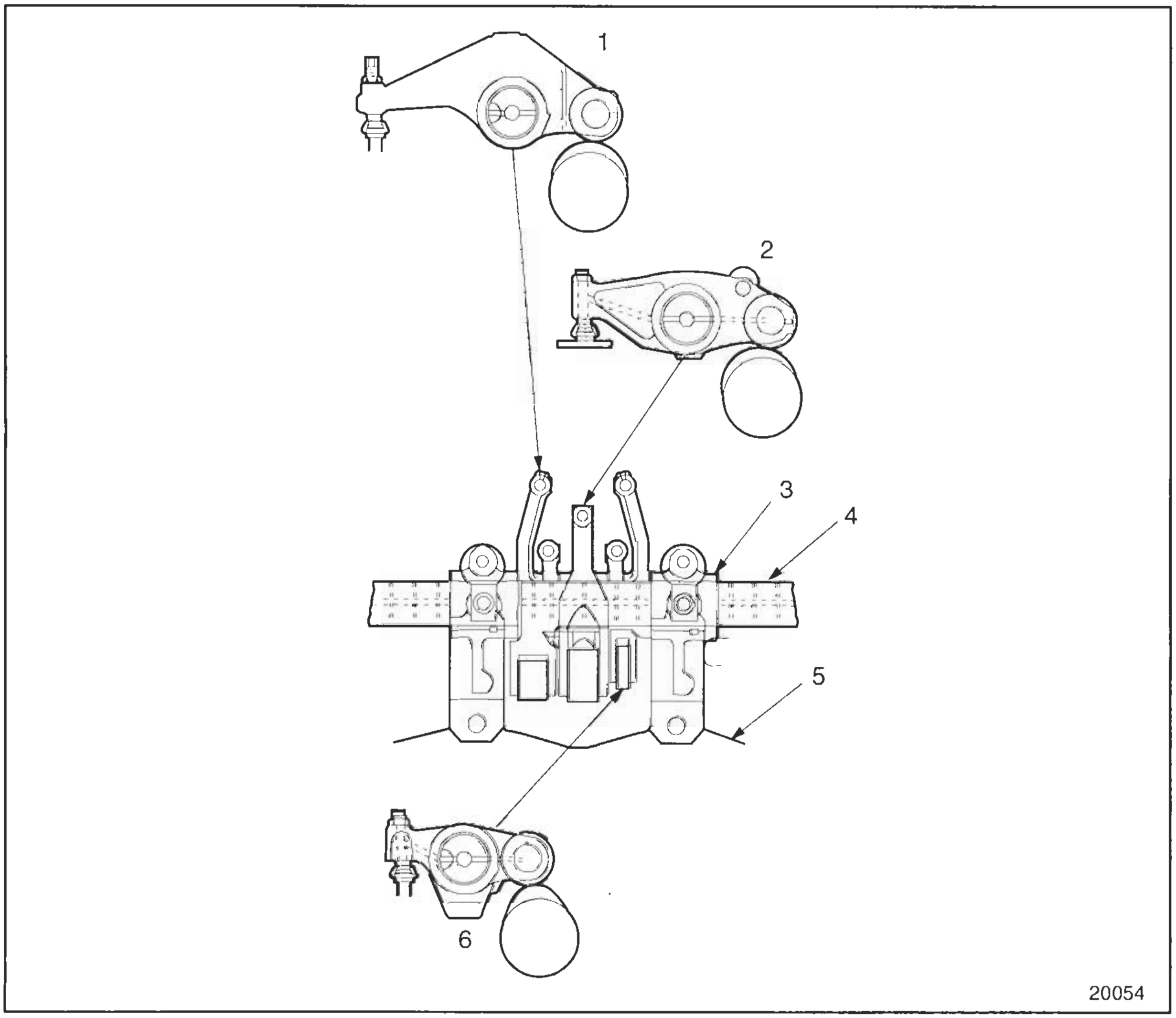
The current assembly has a honed rocker arm shaft bushing, a ceramic cam follower and a new phosphated (black in color) rocker arm shaft which provides improved wear characteristics. The phosphated surface is required for the proper break-in of the steel rocker arm shaft bushings.

A spacer is installed between the rocker arm shaft and the mounting bolts or nuts rather than a washer. This allows the rocker arm shaft to be rotated when installing new rocker arms. When reusing rocker arm assemblies, the rocker shaft should not be rotated so that the same surfaces of the rocker arm assemblies and rocker arm shafts are in contact with each other.

Vertical oil passages at the front and rear of the cylinder head deliver oil from the cylinder block front and rear oil galleries to the No. 1 and 5 lower camshaft bearing saddles. From there, the oil is directed upward (through the enlarged stud hole) to the No. 1 and 5 upper bearing caps. A drilled passage in each of these caps exits at the rocker arm shaft seat area, where it indexes with a hole in each rocker arm shaft.

The rocker arm shafts have internal oil passages that deliver oil to the rocker arm bushings and intermediate upper camshaft bearings. Some of the oil supplied to the rocker arm bushings passes through the oil hole in the bushing to the rocker arm assembly. The rocker supplies oil to the camshaft roller follower, the roller pin and the roller bushing. The rocker arm assemblies also contain drilled passages that supply oil to the valve adjusting screw, valve button, retainer clip, intake and exhaust valve stems and the fuel injector follower.

The No. 3 camshaft cap is "Y" drilled, forming an oil path connection between the front and rear rocker arm shafts, to ensure complete lubrication. The oil passages within one rocker arm cylinder set are illustrated in, see Figure 1–43.



1. Exhaust Rocker Arm Assembly
2. Fuel Injector Rocker Arm Assembly
3. Camshaft Cap
4. Rocker Arm Shaft
5. Cylinder Head
6. Intake Rocker Arm Assembly

Figure 1–43 Rocker Arm Assembly Lubrication Schematic

1.3.1 Repair or Replacement of Valve and Injector Operating Mechanism

To determine if repair is possible or replacement is necessary perform the following procedure. See Figure 1–44.

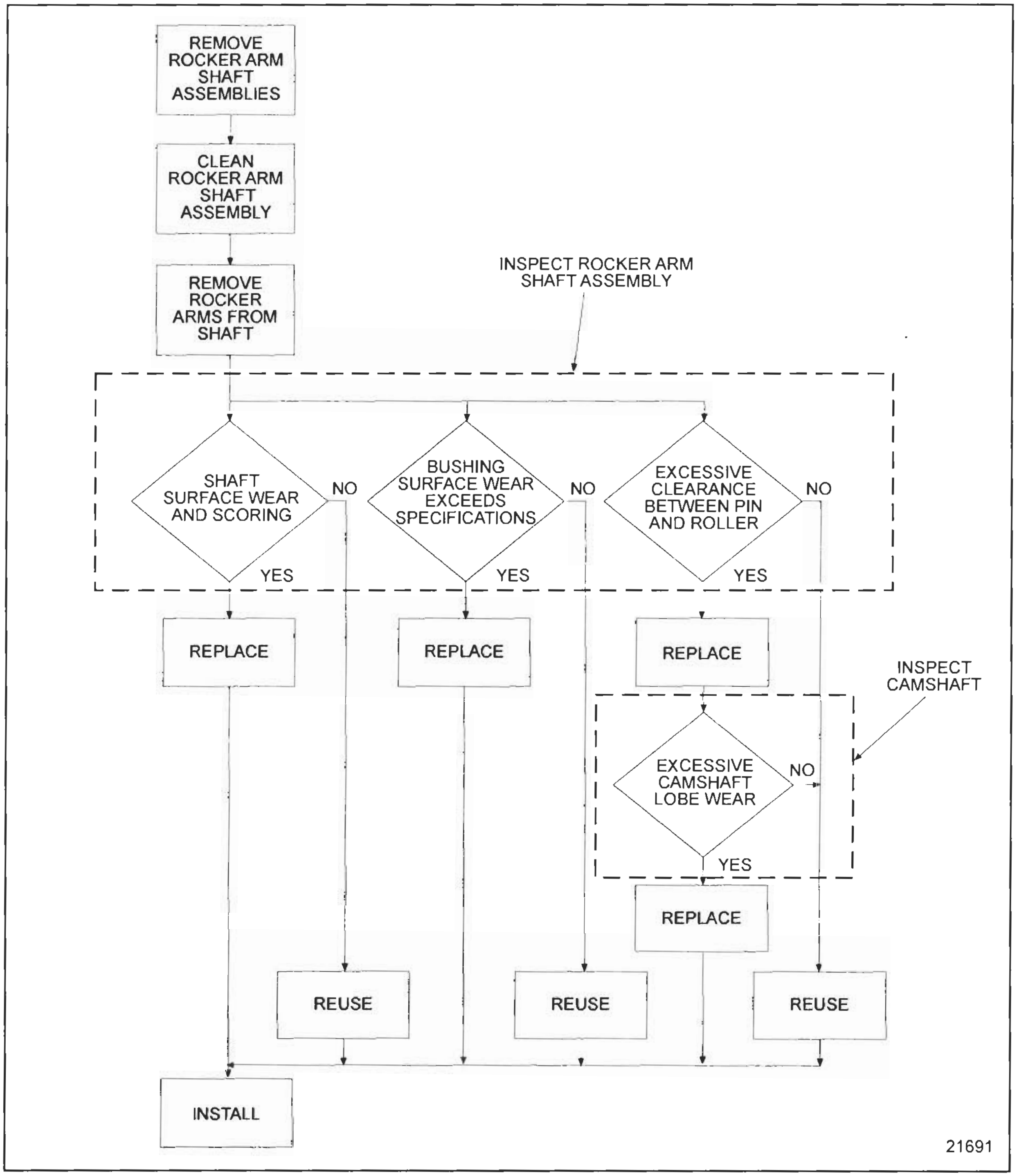


Figure 1–44 Flowchart for Repair or Replacement of Valve and Injector Operating Mechanism

1.3.2 Removal of Rocker Arm Assembly

Perform the following steps for rocker arm assembly removal:

NOTE:
If unit is equipped with Jake brakes, remove brake. Refer to section 1.29.2.

1. If necessary, steam clean the engine around the valve rocker cover/cylinder head mating area.
2. Remove the valve rocker cover. Refer to section 1.6.2.

NOTE:
Whenever nuts No. 1 or No. 8 are loosened or removed, the torque on the corresponding rocker shaft stud must be checked. Tighten to 101–116 N·m (75–86 lb·ft) torque.

3. Remove the rocker arm shaft bolts (No. 2, 3, 4 or 5) and nuts (No. 1 or 6) that retain the rocker arm shaft assembly to the cylinder head. See Figure 1-45. For camshaft or cylinder head removal, both rocker arm shaft assemblies must be removed.

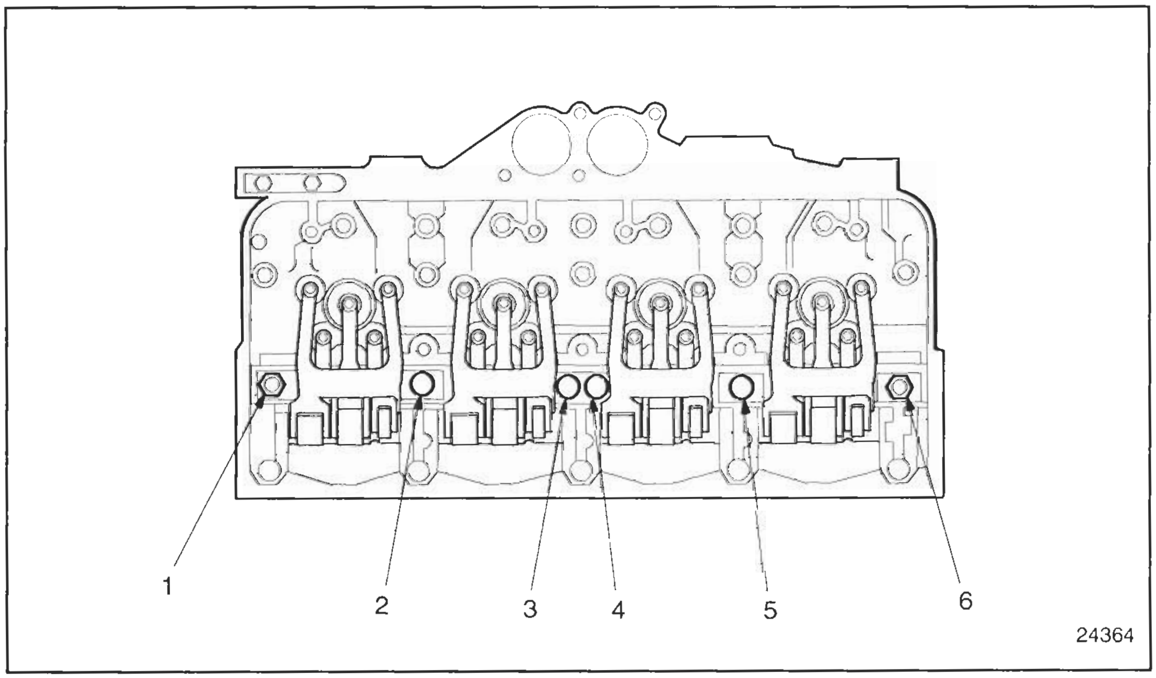


Figure 1–45 Rocker Arm Shaft Bolts and Nut Identification Numbers

NOTE:
Some engines may be equipped with ceramic injector rollers. Use extra caution while removing and handling.

4. Use rocker arm and shaft assembly lifter tool, J 39647-A to remove the rocker arm shafts, with rockers in place. See Figure 1-46.

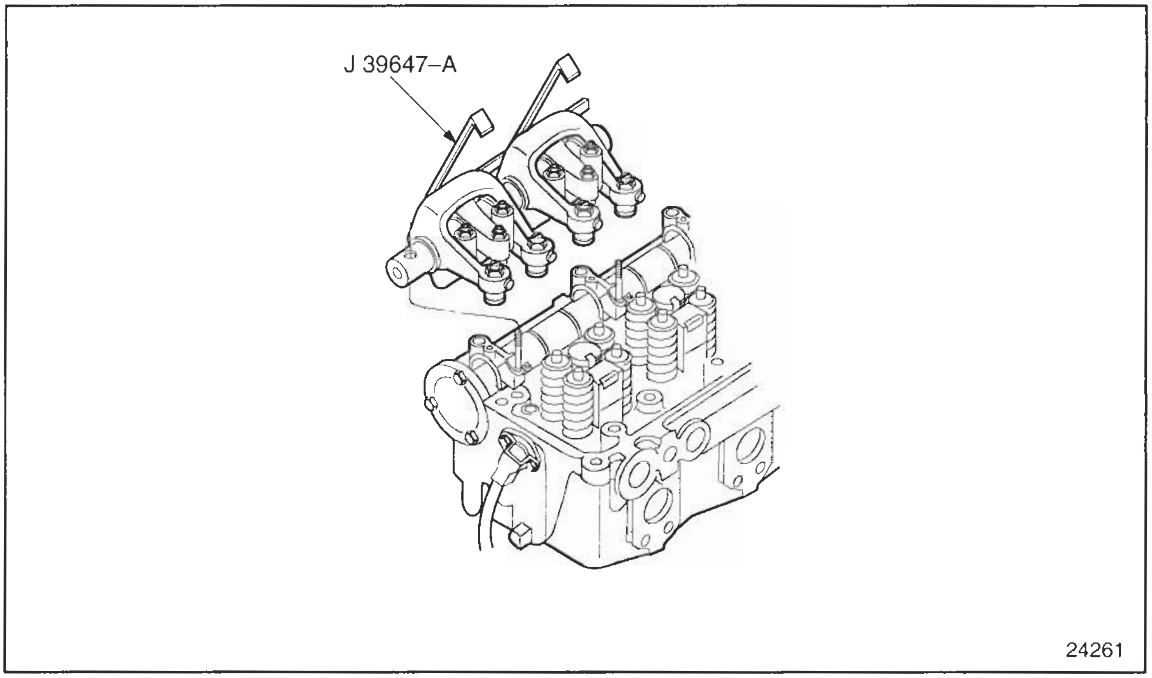


Figure 1–46 Rocker Arm Shaft Assembly Removal and Installation

5. To replace the valve button or valve button retaining clip the valve adjusting screw must be removed from the rocker arm as follows:

NOTICE:
To avoid possible component damage, the valve button retainer MUST NOT be expanded more than 15.5 mm (.610 in.). An adjusting screw is provided on the expander tool to limit the amount of travel.

[a] Spread the retaining clip with expander, J 36347 and remove the button. See Figure 1-47.

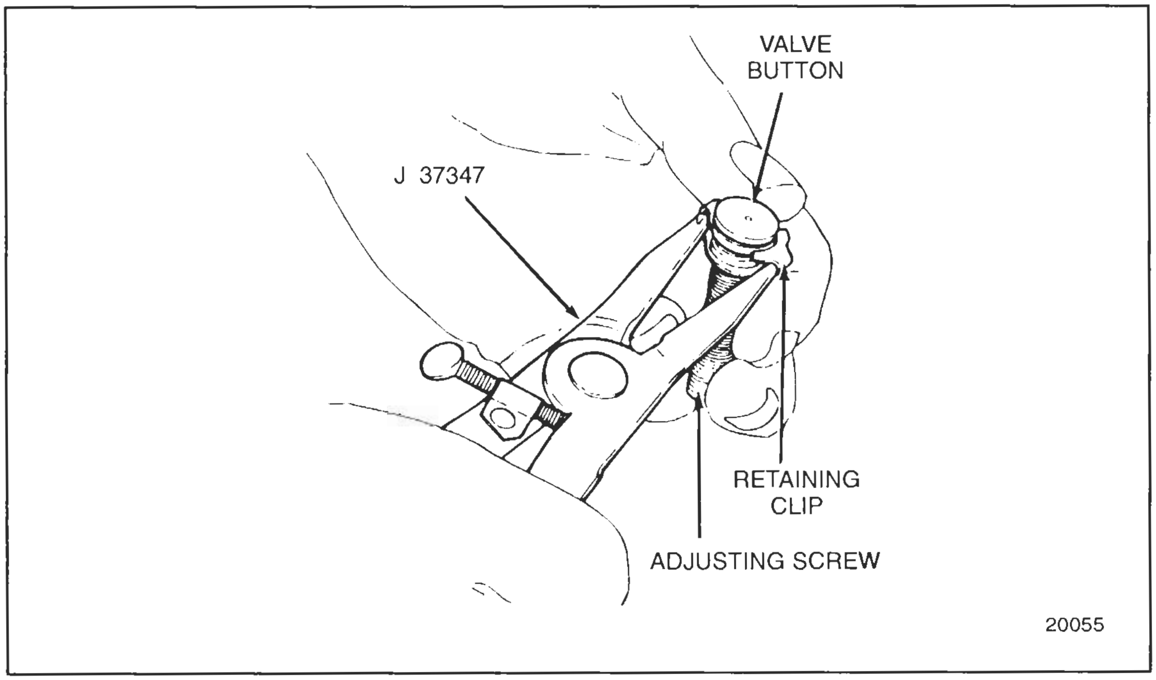


Figure 1–47 Valve Button Retainer Clip Removal and Installation

[b] Slide the retaining clip, open end first, down the adjusting screw. It is necessary to spread the clip slightly so that the open end can pass over the ball head of the adjusting screw.

[c] Insert the tips of the expander, J 36347, between the legs of the retaining clip and expand the clip.

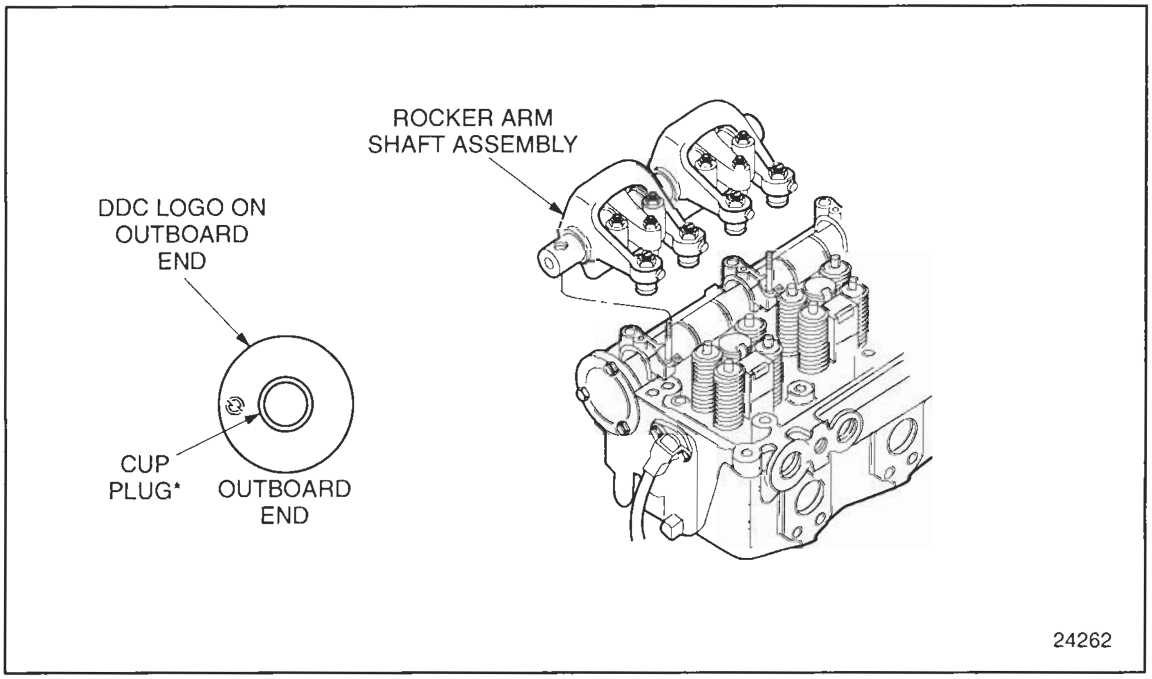
[d] Insert the groove on the valve button into the legs of the retaining clip.

[e] Remove the expander and hold the legs of the retainer with the thumb and index finger.

[f] Press the valve button towards the screw to seat both legs of the retainer completely in the groove.

NOTICE:
Front and rear rocker arm shaft sections look identical, but must not be reversed, and must be installed as removed, due to bolt hole center line distances. The DDC logo is stamped on the outboard end of each rocker shaft to ensure correct assembly and installation. See Figure 1–48.

6. If further disassembly is necessary, slide the rocker arm assemblies off the rocker arm shafts, marking or segregating the parts so that they may be reinstalled in the same position from which they were removed.



* Must be installed 1.0–1.3 mm (.040–.050 in.) below surface using tool J 36326

Figure 1–48 Rocker Arm Shaft Identification

Clean the rocker arm assemblies as follows:

1. Remove the cup plug at one end of the rocker arm shafts to facilitate the removal of any foreign material lodged behind the plug.

NOTICE:
Do not soak the rocker arm assemblies in solvent because this will remove the lubricant from the cam follower roller bushings.

2. Clean the exterior of the rocker arm assemblies only.

CAUTION:
To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

3. Blow dry with compressed air.
4. Soak the rocker arm shaft in clean fuel oil.
5. Run a wire brush through the oil passage to remove any foreign material or sludge.

CAUTION:
To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

6. Clean the exterior of the shaft and blow out the passages and oil holes and dry with compressed air.

1.3.2.1 Inspection of Rocker Arm Assemblies and Camshaft Lobes

Inspect the rocker arm assemblies and camshaft lobes as follows:

1. Install new cup plugs with tool J 36326 until they are 1.0–1.3 mm (.040–.050 in.) below the surface of the shaft. See Figure 1–48.
2. Remove all of the old gasket sealer from the joint face of the No. 1 and 5 camshaft bearing caps and the cylinder head.

NOTE:
Refer to "Gasket Eliminator" in the "General Information" section at the beginning of this manual.

Prior to inspection:

1. Inspect the rocker arm shaft bushing surfaces and rocker arm bushing bores for wear or scoring.
2. Check the cam follower rollers for scoring, pitting, or flat spots.
   [a] Clearance between the rollers and pins should not be more than 0.08 mm (.003 in.).
   [b] Replace as necessary.
3. Check to be sure they turn freely on the roller pins.
4. Inspect the camshaft lobes and journals for scoring, pitting, or flat spots. If there is a doubt as to the acceptability of the camshaft for further service, determine the extent of camshaft lobe wear. Refer to section 1.22.

1.3.3 Installation of Rocker Arm Shaft Assembly

Perform the following for rocker arm assembly installation:

1. Make sure the cup plugs are properly installed to each end of the rocker arm shafts before the shafts are installed to the engine. See Figure 1–48. Refer to section 1.3.2.1 step 1.
2. Check the torque on the rocker shaft studs to be sure they were not loosened when the nuts were removed.
3. Tighten the studs to 101–116 N·m (75–86 lb·ft) torque.
4. Install the adjusting screws, valve buttons and clips to the rocker arm assemblies if they were removed. See Figure 1–42.

NOTE:
When a new rocker arm is installed on a phosphated shaft, the shaft should be turned 180° to present a fresh phosphated area to the loaded region of the bushing.

5. Install the rocker arms to the rocker arm shafts in their original positions. Use the rocker arm identification marks to ensure correct component assembly. If the rocker shaft does not have flats, decide on the position of the worn surfaces and rotate the rocker shaft accordingly.
6. Using care to locate the valve buttons to their respective valve stems and injector followers, install the rocker arm shaft assemblies to the cylinder head using J 39647–A. See Figure 1–46.
7. If the rocker arm shafts do not have flats in the bolt hole locations, rocker shaft spacers are required.
   [a] In this case, install the rocker shaft spacers on the cap bolts and studs.
   [b] If the rocker arm shafts do have flats in the bolt hole locations, rocker shaft spacers are not required.

NOTE:
If new rocker arm components are installed, engine oil should be poured over the rocker arms, rocker shaft, and camshaft as a pre–lubricant.

8. Install the inboard camshaft cap bolt through the rocker arm shaft and camshaft cap and into the cylinder head.
9. Install the nuts to the No. 1 and 5 cap studs.

10. Tighten the rocker arm shaft retaining bolts and nuts to 101–116 N·m (75–86 lb·ft) torque using the sequence. See Figure 1–49.

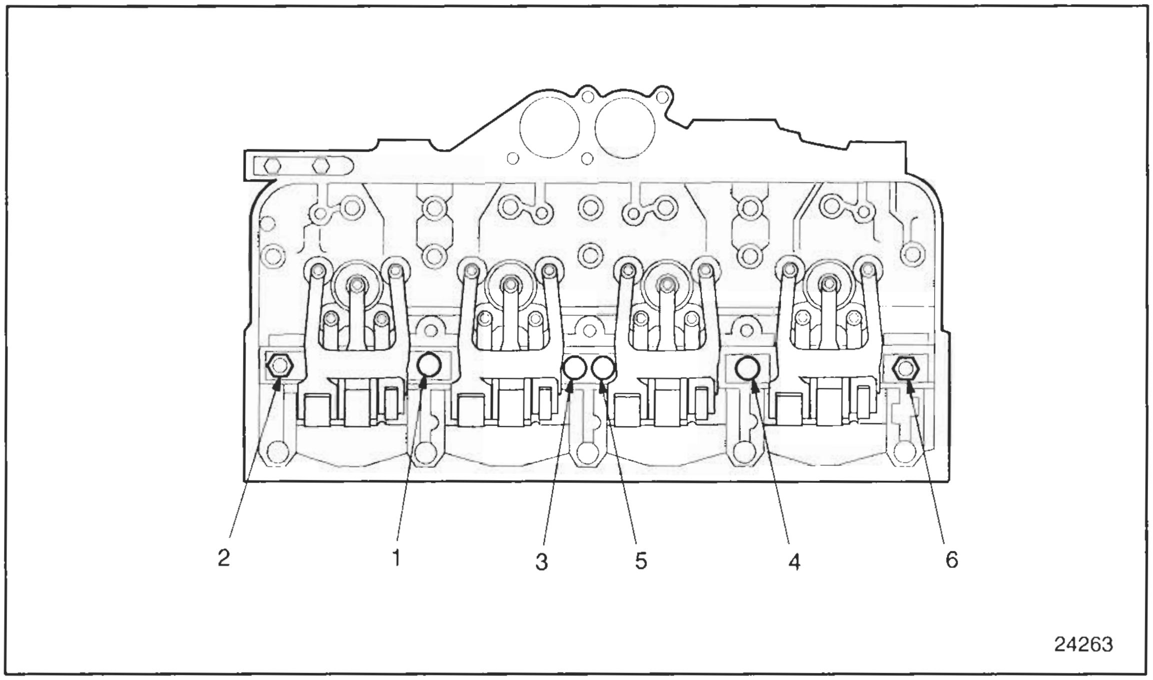


Figure 1–49 Rocker Arm Shaft Retaining Bolt and Nut Tightening Sequence

11. Adjust the intake and exhaust valve clearances and set the injector heights. Refer to section 12.2.
12. Install the rocker cover. Refer to section 1.6.4.
13. Install any other components that were removed for this procedure.
14. Start the engine and check for leaks.

1.4 VALVES, SPRINGS, GUIDES, INSERTS, SEALS AND ROTATORS

Four valves per cylinder, two intake and two exhaust, give the Series 50 Engines excellent breathing and cooling characteristics. See Figure 1–50. Each valve has a single valve spring. See Figure 1–51.

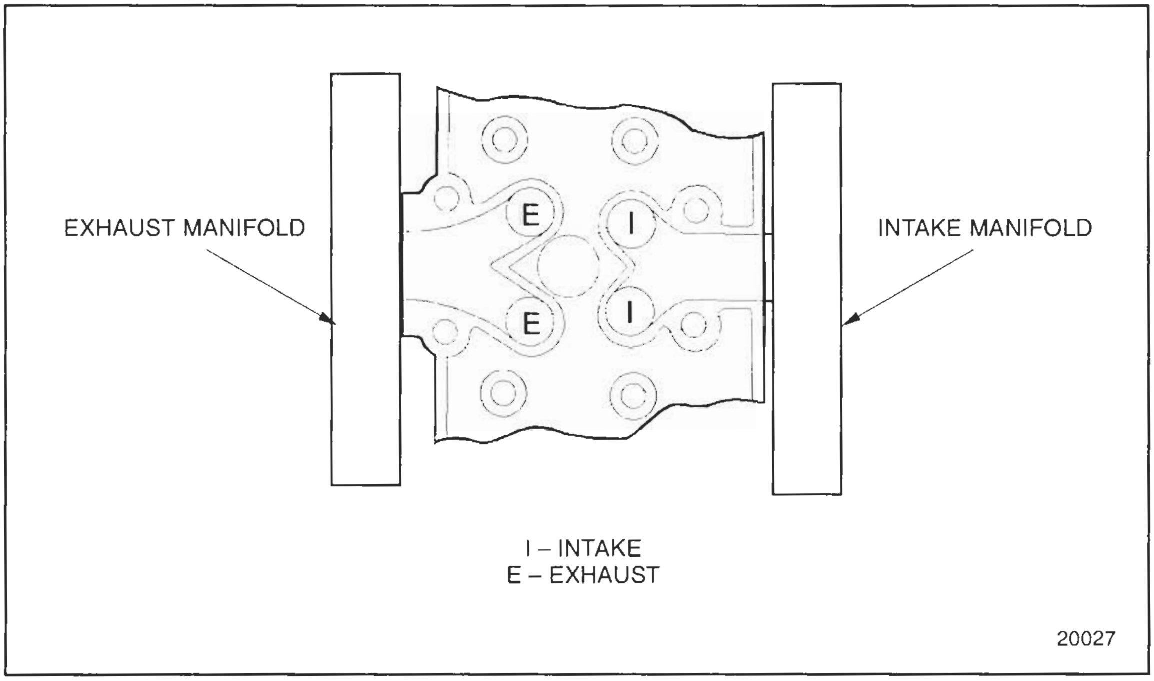
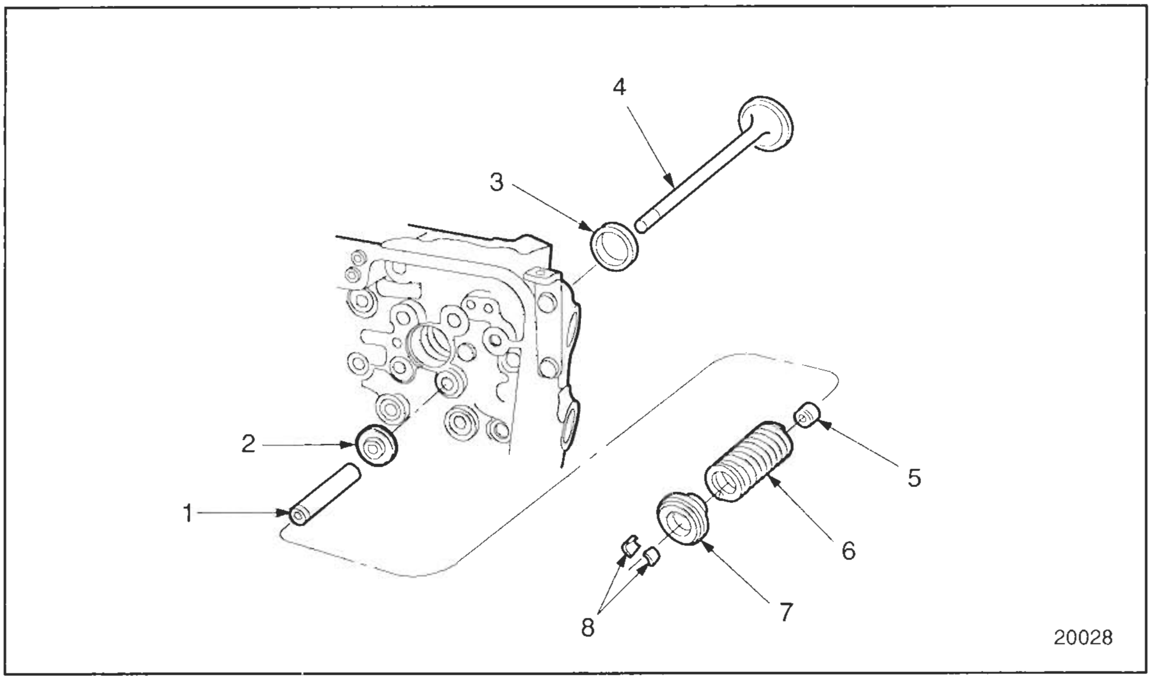


Figure 1–50 Intake and Exhaust Valve Arrangements

Valves are made of heat-treated alloys, with heads and stems precision ground. Stem ends are hardened to minimize wear in contact with the valve rocker buttons.

Hard-alloy valve seat inserts, pressed into both intake and exhaust ports, can be replaced when worn to restore new engine performance.

Valves are positioned and aligned by replaceable valve guides pressed into the cylinder head. See Figure 1–51.



1. Valve Guide
2. Valve Spring Seat
3. Valve Insert
4. Valve
5. Valve Stem Oil Seal
6. Valve Spring
7. Valve Rotator
8. Valve Keepers

Figure 1–51 Valve, Valve Seat, Valve Guide, Springs and Rotators

Replacement guides are reamed to close tolerances, and do not require reaming after installation.

All valves are retained by valve rotator spring caps and two–piece tapered valve locks.

Valve stem oil seals, installed on both intake and exhaust valves, provide controlled valve stem lubrication while limiting oil consumption.

NOTE:
New valve seat inserts are pre–ground and only need to be checked for concentricity after installation. Do not grind a new seat insert unless eccentricity exceeds 0.05 mm (0.002 in.). Before grinding, be sure the valve guide is not excessively worn or bent, which could cause an erroneous eccentricity reading. If the firedeck has been resurfaced, the valves will have to be seated deeper to restore the valve head recess depth to specification limits. Do not grind seat inserts for this purpose. Reduced thickness inserts are available that are 0.2540, 0.5080 and 0.7620 mm (.010, .020 and .030 in.) shallower than standard. When a reduced thickness valve seat insert is used, a correspondingly thicker valve spring seat must be used. Maximum allowable valve seat width and minimum valve stem diameter are shown in, see Figure 1–52 and see Figure 1–53.

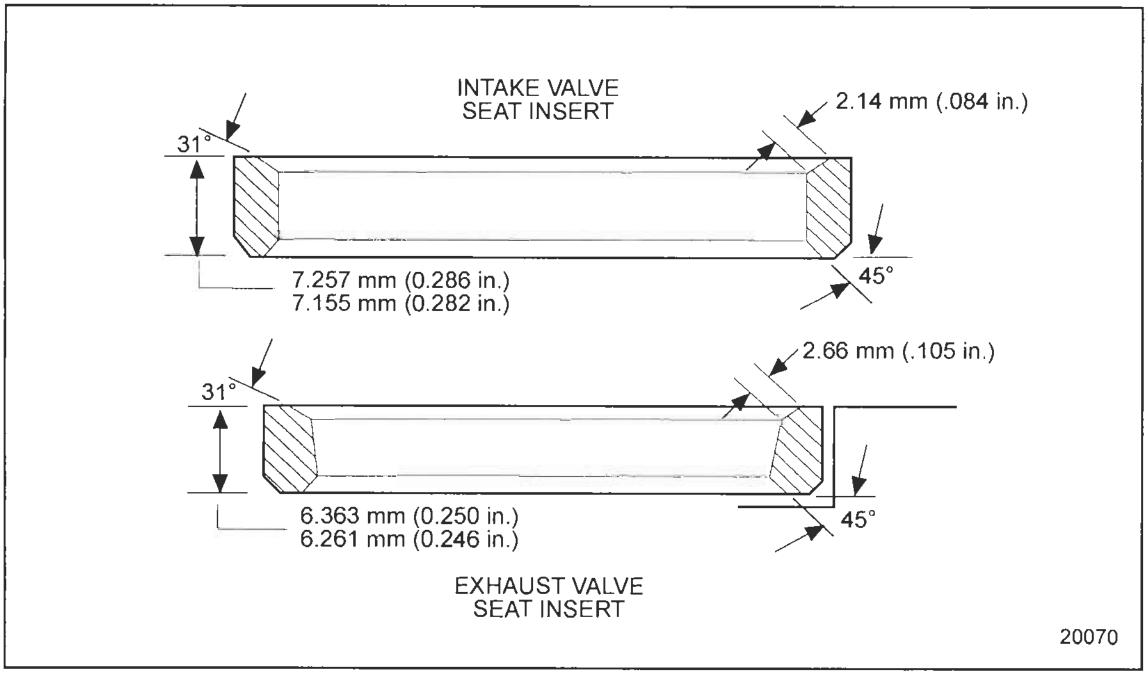


Figure 1–52 Standard Valve Seat Insert Thickness

When servicing exhaust valves, determine which type of exhaust valve is contained in the engine. If an exhaust valve must be replaced, use the same type that was removed. Do not mix exhaust valve types within an engine. Both exhaust valves are available from service stock for this purpose. Exhaust valve lash settings are affected by the type of exhaust valve that is contained in the engine. The valve lash settings and injector timing height are listed on the rocker cover. Refer to section 12.2.

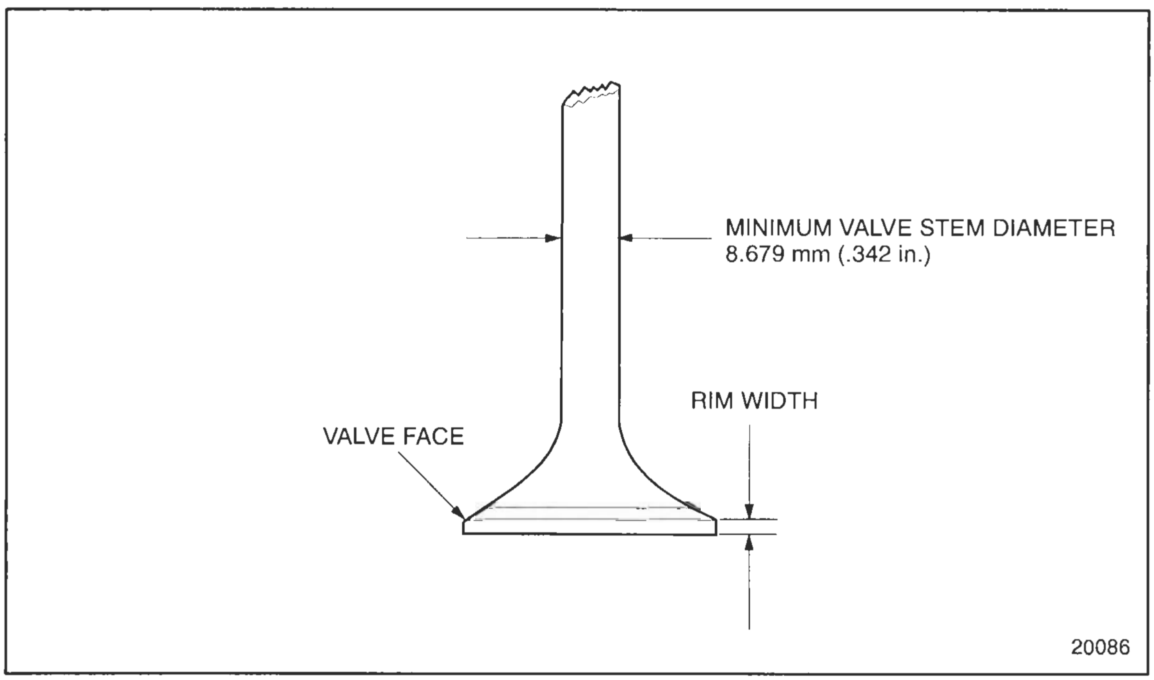


Figure 1–53 Minimum Valve Stem Diameter

Series 50 Engines use an austenitic based alloy which can be identified by a forged H on the combustion face, and by a machined identification ring above the valve lock groove. See Figure 1-54.

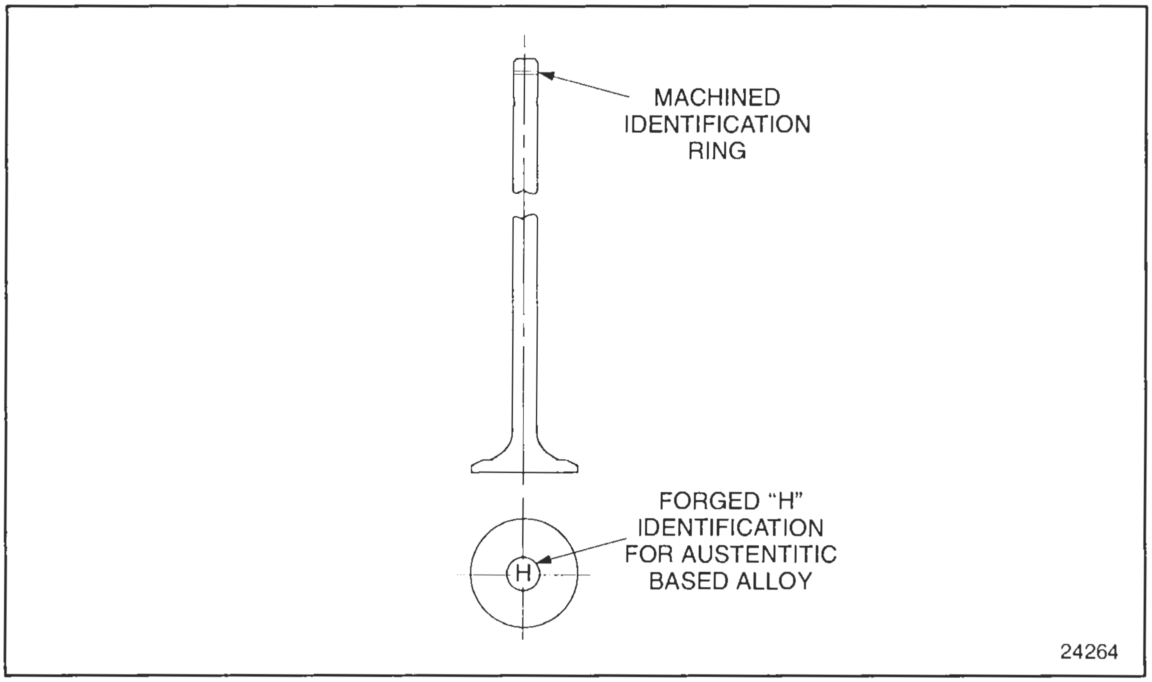


Figure 1–54   Exhaust Valve Identification

1.4.1 Repair or Replacement of Valves

To determine if repair is possible or replacement is necessary perform the following procedure. See Figure 1–55.

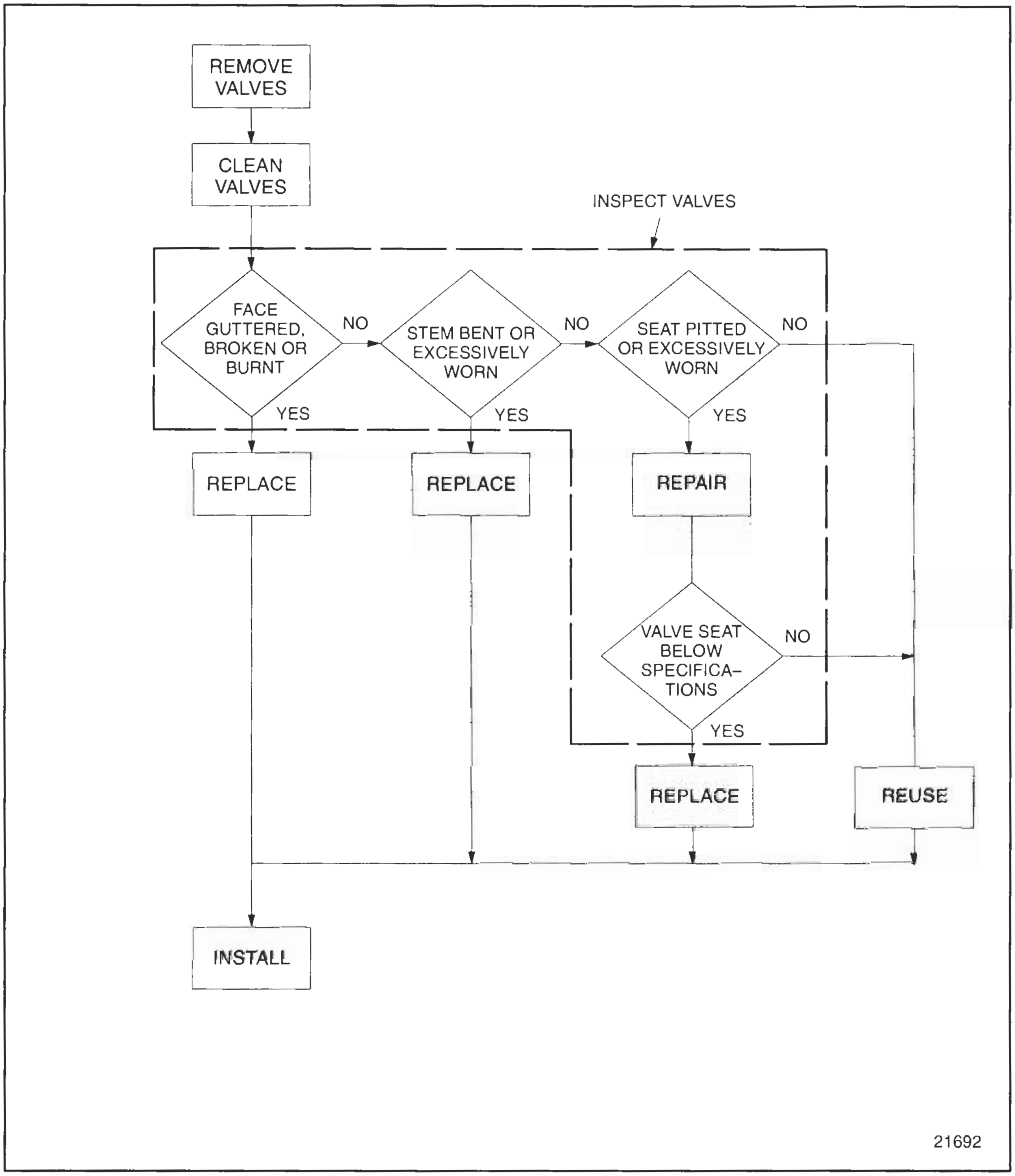


Figure 1–55 Flowchart for Repair or Replacement of Valves

1.4.2 Removal and Cleaning of Valve Spring (Cylinder Head Installed)

Perform the following steps for valve spring removal:

1. Clean any dirt and debris from the rocker cover joint area around the top of the cylinder head. Remove the rocker cover. Refer to section 1.6.
2. If the engine has a Jake Brake, remove the Jake Brake housings that cover the rocker arm and shaft assembly for the valve to be serviced, refer to section 1.29.2.
3. Remove the rocker arm shaft assembly; refer to section 1.3.2.

NOTE:
Fuel must be removed from the cylinder head fuel galleries prior to removing the injectors. Refer to section 2.2.

4. Remove the injector from the appropriate cylinder. Refer to section 2.2.2.
5. Insert the threaded portion of the valve spring compressor, J 35580 into the threaded inboard camshaft cap hole adjacent to the valve being worked on. See Figure 1–56.

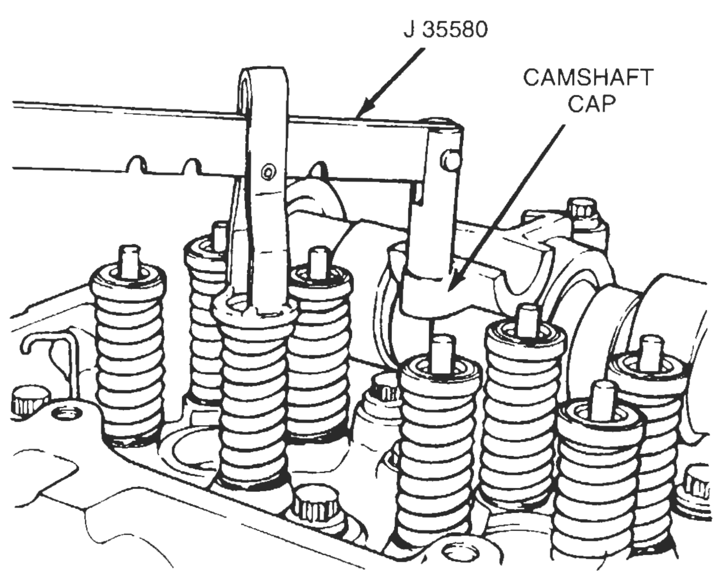


Figure 1–56 Installing Valve Spring Compressor

6. Position the spring compressor cage portion of the valve spring compressor directly over the valve spring to be compressed. Engage the dowel of the cage in the closest slot of the valve spring compressor handle.

NOTICE:
Do not contact the valve with the compressor tool, as the spring will be damaged.

7. Compress the valve spring and remove the valve locks using a small magnet to prevent the locks from falling into the cylinder head oil return galleries. See Figure 1-57.

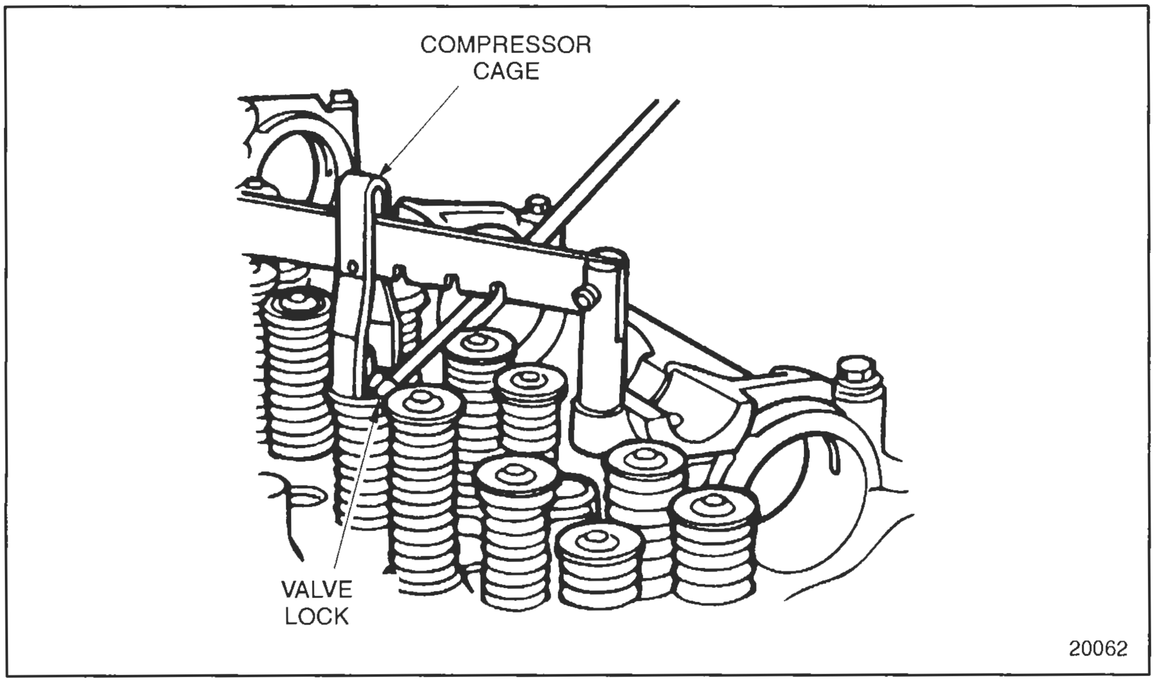


Figure 1–57 Compressing Valve Spring

8. Release the spring and remove the valve rotator and valve spring.
   [a] If the valve stem oil seal is to be replaced, remove the seal and discard it.
9. Repeat step 1. through step 8. on the other three valves for the cylinder being worked on.

NOTE:
All valve spring or seal removal and replacement must be completed for each cylinder being serviced while the piston is at top-dead-center, before turning the crankshaft to work on another cylinder.

1.4.3 Removal and Cleaning of Valve Spring (Cylinder Head Removed)

With the cylinder head assembly removed from the engine, remove the valve springs as follows:

1. Bolt the engine overhaul stand adaptor, J 39652, to the engine overhaul stand, J 29109, using the hardware provided with the adaptor. See Figure 1–58.

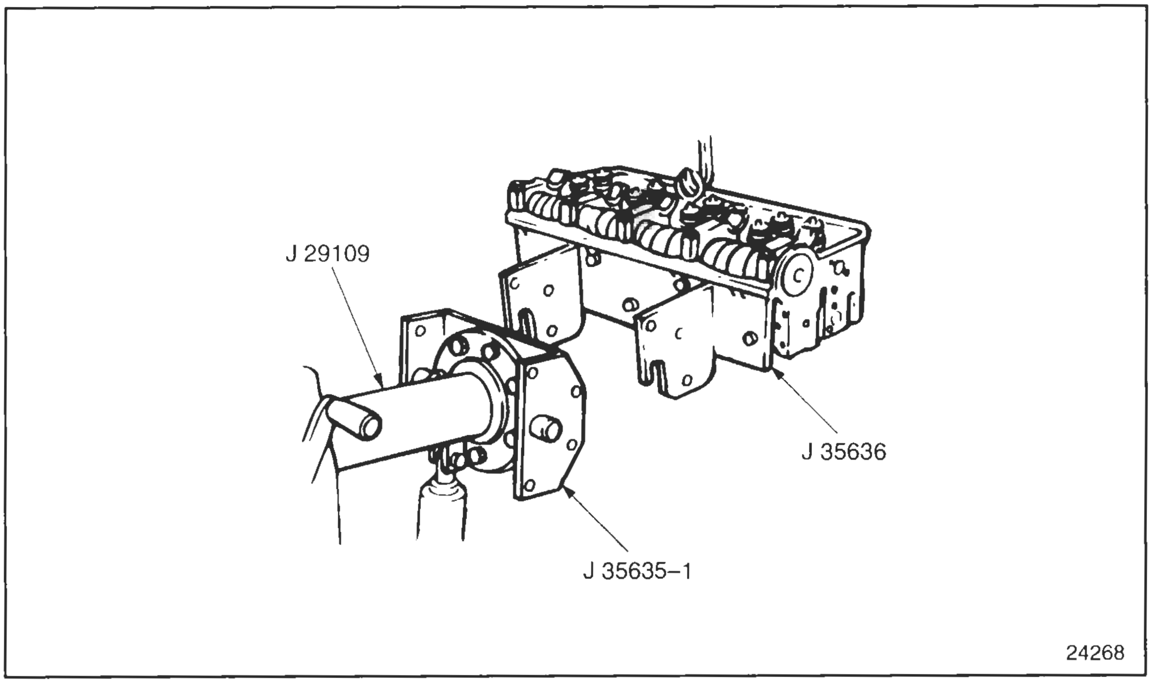


Figure 1–58 Engine Overhaul Stand

2. Bolt the cylinder head adaptor plate, J 35636–A, to the cylinder head using the bolts provided with the adaptor.
3. Mount the cylinder head and adaptor plate to the overhaul stand adaptor by engaging the slots in the cylinder head adaptor plate to the dowels on the overhaul stand adaptor.
4. Install the six nut and bolt assemblies that secure the cylinder head adaptor plate to the overhaul stand adaptor.
5. Remove the cylinder head lifting hardware.
6. Turn the crank of the engine overhaul stand to position the cylinder head in an upright position.

NOTICE:
Do not contact the valve with the compressor tool, as the spring will be damaged.

7. Use valve spring compressor, J 8062-1, with jaws, J 8062-3 installed, to compress each valve spring and remove the valve locks. See Figure 1-59. Refer to section 1.4.5.2 for inspection procedures.

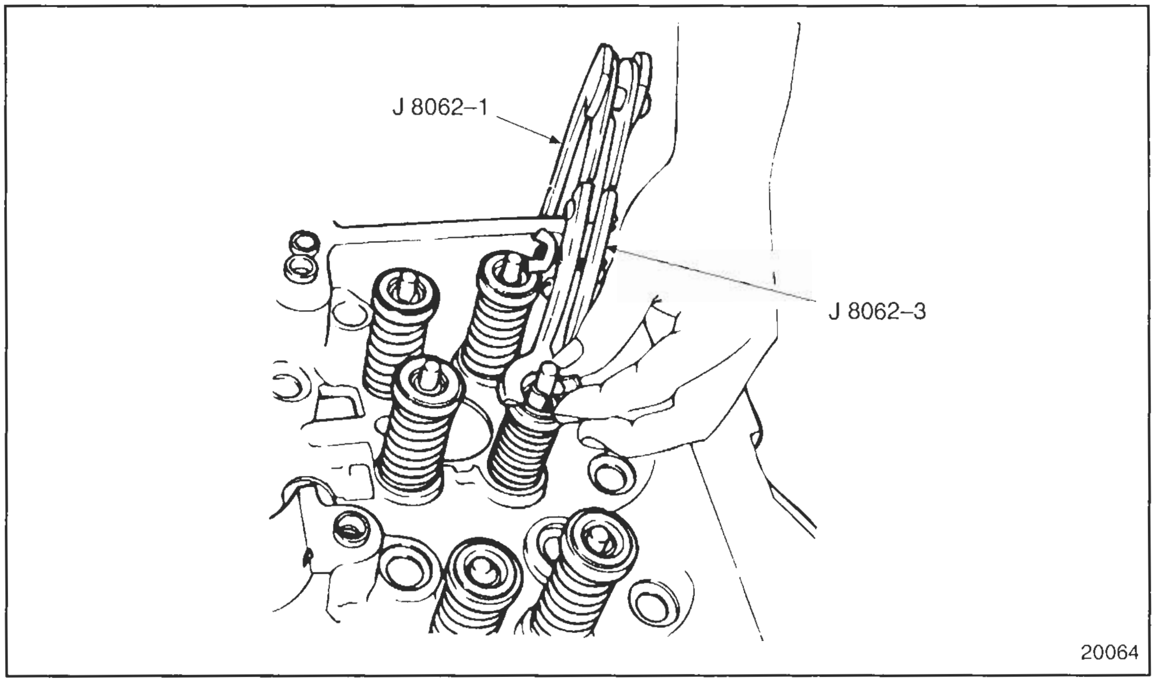


Figure 1–59 Compressing Valve Spring

8. Release the spring and remove the valve, valve rotator and valve spring.
9. Remove the valve stem oil seal and discard the seal.
10. Remove the valve spring seat.
11. As parts are removed, mark or segregate them according to their original position for possible reuse.

1.4.3.1 Cleaning of Valves

Clean the valves and parts as follows:

CAUTION:
To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

1. Using proper eye protection, clean all of the disassembled parts with fuel oil and dry with compressed air.

1.4.3.2 Cleaning of Valve Stems

Perform the following for valve stem cleaning:

1. Clean the carbon from the valve stems and wash the valves with fuel oil.

1.4.3.3 Cleaning of Valve Guide Bore

Perform the following for valve guide bore cleaning:

1. Clean the valve guide bore with bore brush, J 5437 (or equivalent), to remove all gum and carbon deposits.

1.4.4 Valve Guide Removal

Perform the following steps for valve guide removal:

1. Assemble the valve guide remover, J 34696-B, to an air chisel. See Figure 1-60.

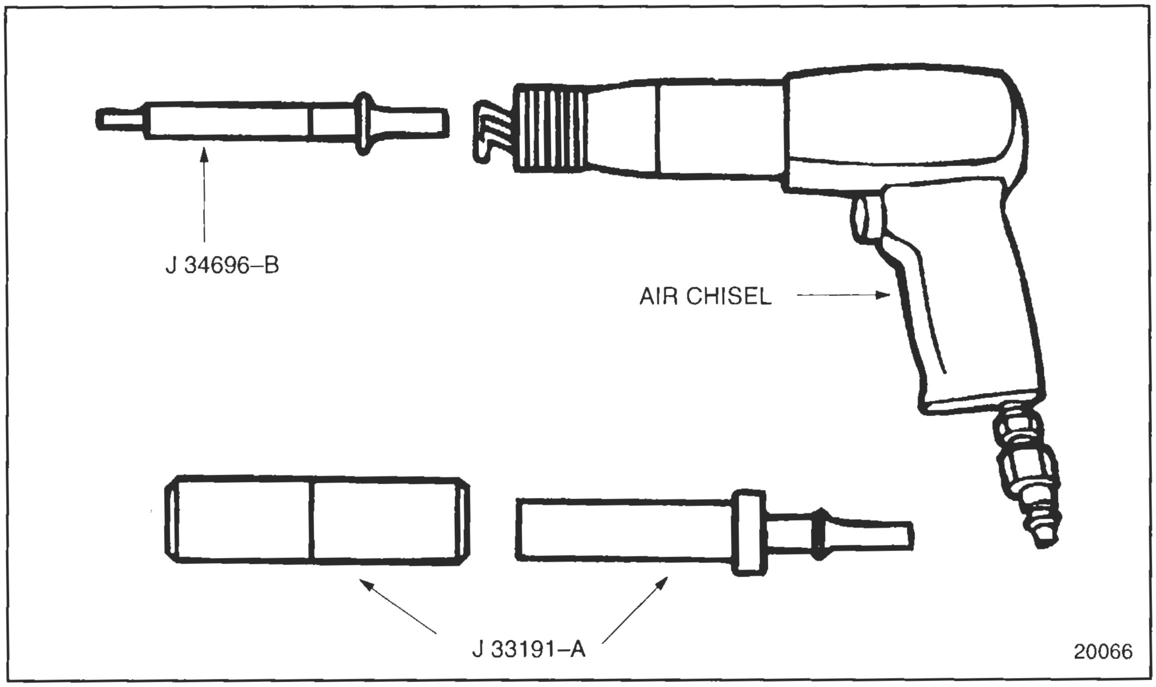


Figure 1–60 Valve Guide Remover

2. Position the cylinder head firedeck side up on a turn over stand or supported on 102 x 102 mm (4 x 4 in.) wooden blocks on a workbench.

3. Insert the tool into valve guide from the firedeck side of the cylinder head. See Figure 1-61.

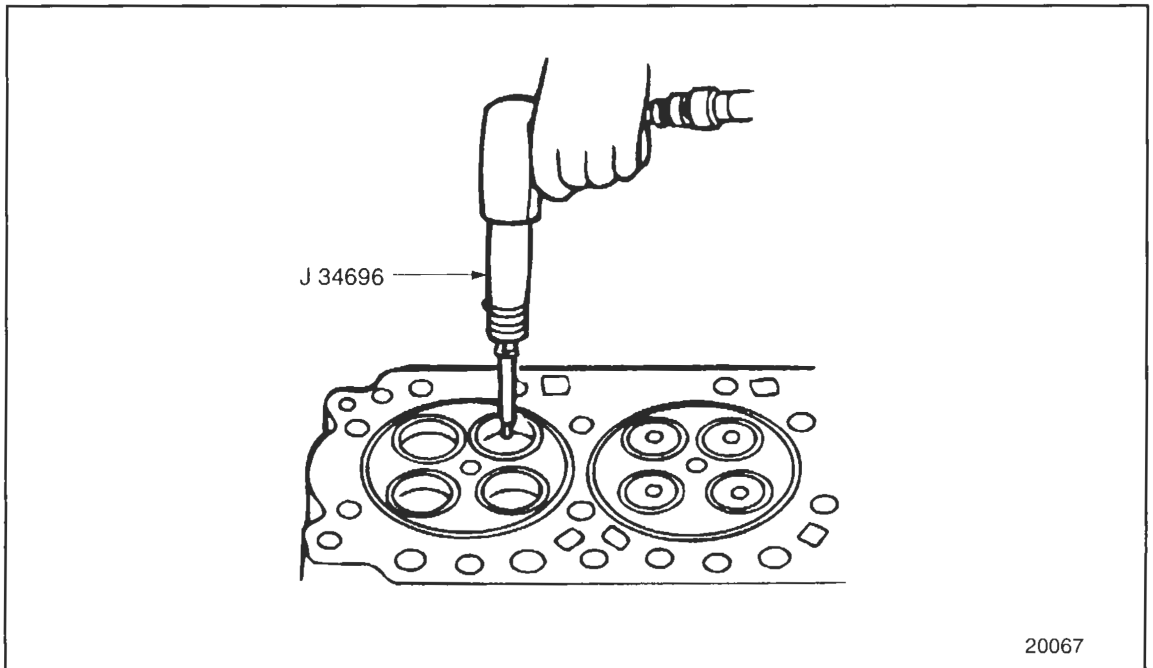
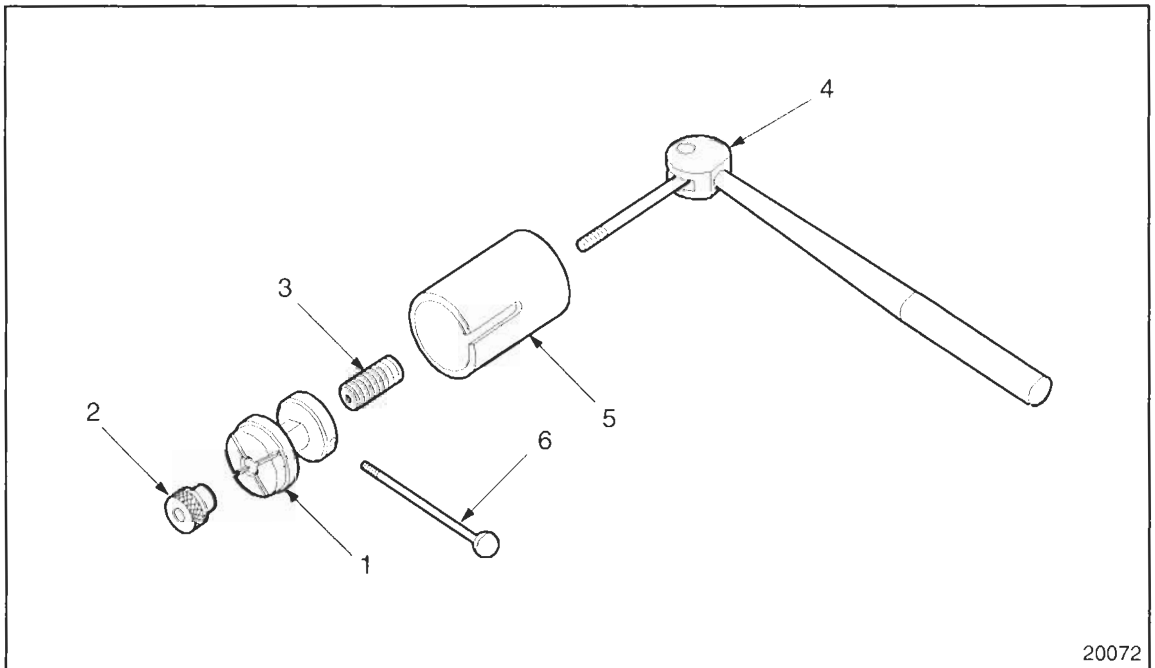


Figure 1-61 Valve Guide Removal

4. Hold the tool vertical to the cylinder head and drive the valve guide until it is free of the cylinder head.

1.4.5 Removal of Intake and Exhaust Valve Seat Insert

As the intake and exhaust valve seats are different in size, two different tools are required for removal. Use the cam-operated valve seat remover, J 23479-460A, with collet, J 23479-100, to remove the larger intake valve seat insert. Use valve seat remover, J 23479-271, with collet J 23479-29 to remove the smaller exhaust valve seat insert. See Figure 1-62.



1. Collet
2. Knurled Knob
3. Spring
4. Valve Seat Insert Puller
5. Collar
6. Collet Lever

Figure 1–62 Valve Seat Insert Remover Tools

Remove the intake and exhaust valve seats as follows:

1. Place the cylinder head in a horizontal position with the valve seats facing up.

NOTICE:
Follow instructions supplied with tools J 23479–460A, J 23479–100, J 23479–271, and J 23479–29 to ensure longer tool life and unnecessary collet damage.

2. Follow the instructions furnished with the valve seat remover tool to assemble the remover.
3. Using a new valve seat insert as a guide, turn the knurled knob on the end of the shaft to tighten and expand the collet until the valve seat insert will just slip off the collet. Refer to instructions supplied with the valve seat remover tool for correct tool operation.

1.4.5.1 Inspection of Valve

The valve stems must be free from scratches or scuff marks and the valve faces must be free from ridges or cracks. Some pitting of the valve face is normal, and is acceptable as long as no leak paths are evident. If leak paths exist, reface the valves or install new valves. If the valve heads are warped or the valve stem is bent, replace the valves.

If suitable for reuse, a valve may be refaced as long as the valve rim width, after refacing, is not less than 2.0 mm (.078 in.) for intake valves and 2.2 mm (.086 in.) for exhaust valves. See Figure 1-63.

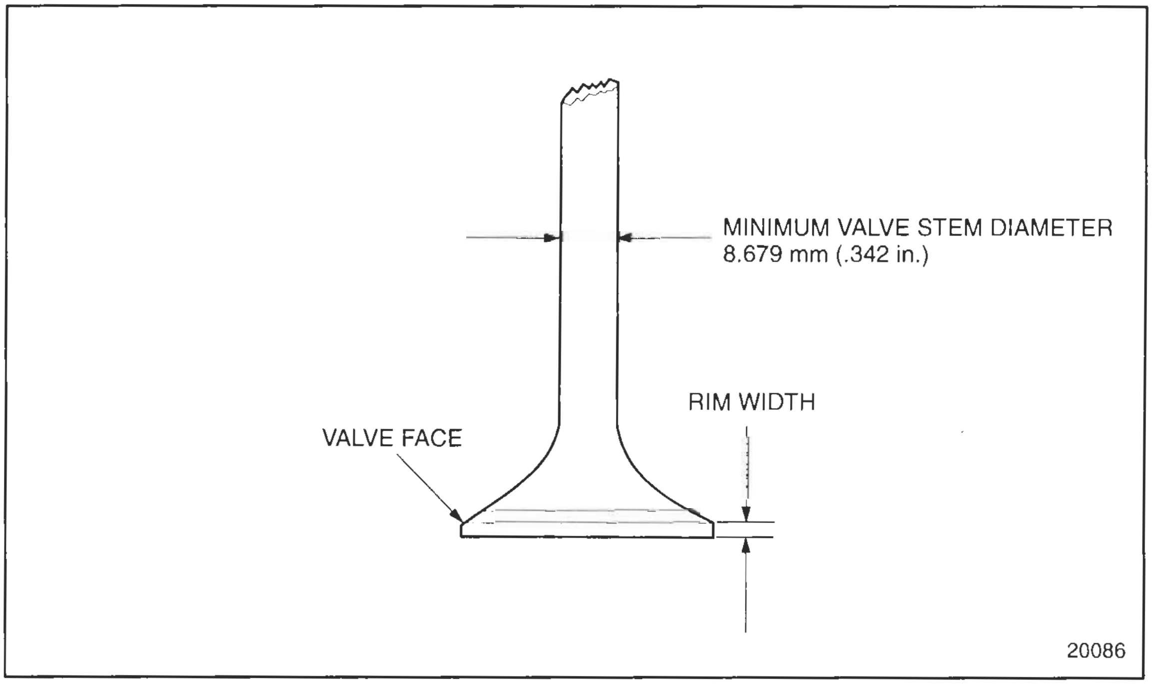


Figure 1–63 Valve Face Refacing and Rim Width

1.4.5.2 Inspection of Valve Springs

Inspect the valve springs and replace any that are pitted or cracked. The entire spring should be inspected. When a broken spring is replaced, the rotator and valve locks for that valve should also be replaced.

Use valve spring tester, J 22738-02, to test the springs. See Figure 1-64.

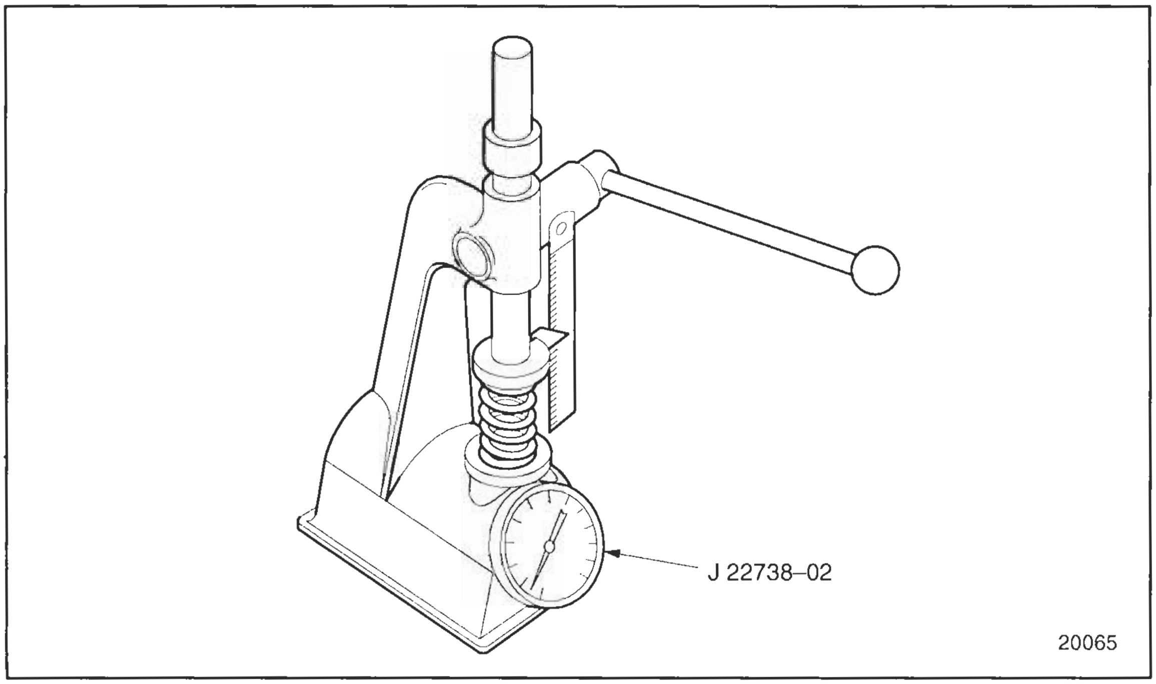


Figure 1-64 Testing Valve Spring Using

If the spring load is less than 297 N (67 lb) at a compressed length of 67.25 mm (2.648 in.), the spring should be replaced and the valve locks should be discarded.

1.4.5.3 Inspection of Valve Guides

Inspect the guides for cracks, chipping, scoring or excessive wear.

Measure the valve guide bore with a small hole gage or gage pin, and measure the valve stem diameter with a micrometer. Compare the measurements to determine valve stem clearance. If the clearance is greater than 0.13 mm (.005 in.), the valve guide must be replaced.

1.4.5.4 Inspection of Valve Seat Inserts

Inspect valve seat inserts for wear, cracking or incorrect seat angle, which should be 31°, standard valve seat insert thickness. See Figure 1-52.

1.4.6 Installation of Intake and Exhaust Valve Seat Insert

Perform the following steps for intake and exhaust valve seat insert installation:

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

1. Clean the seat insert counterbores and the new seat inserts with a suitable solvent and blow dry with compressed air.
2. Use valve seat insert installers, J 33190 (intake), and J 34983 (exhaust), to install new inserts. See Figure 1–65.

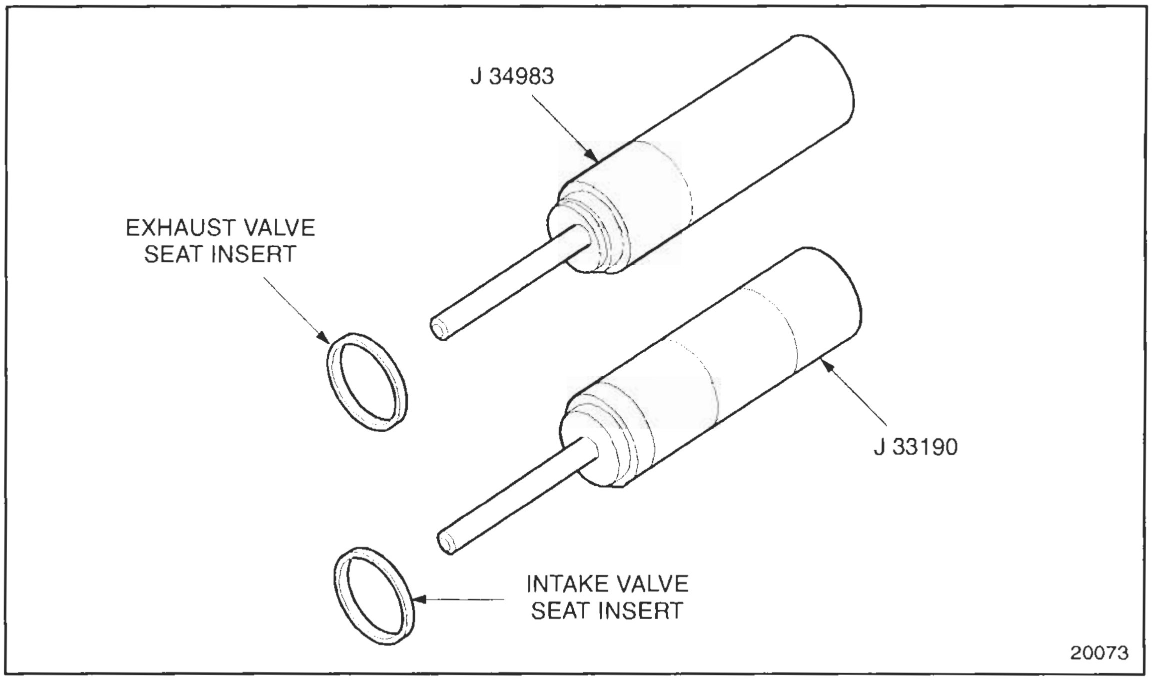


Figure 1–65 Valve Seat Insert Installation Tools

3. Start the insert squarely into its counterbore with the seat facing up. See Figure 1-66.

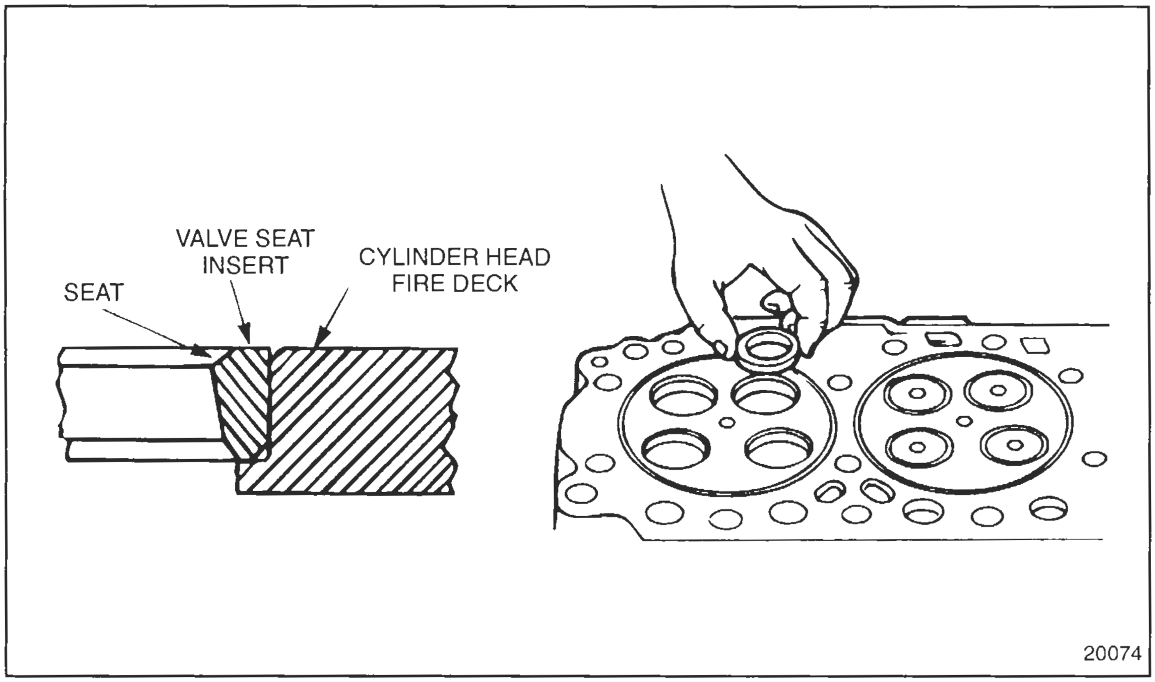


Figure 1–66 Valve Seat Insert Insertion

4. Pilot the installer into the valve guide from the firedeck surface. See Figure 1-67.

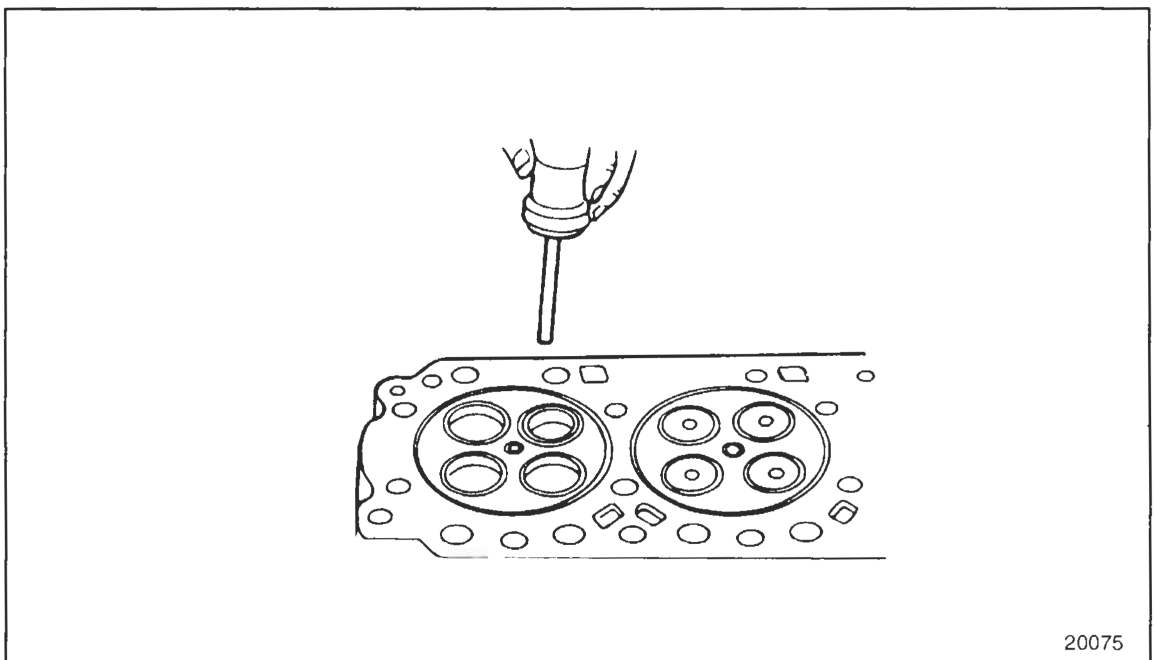


Figure 1–67 Valve Seat Insert Installation

5. Drive the insert solidly into its seat in the cylinder head. See Figure 1-68.

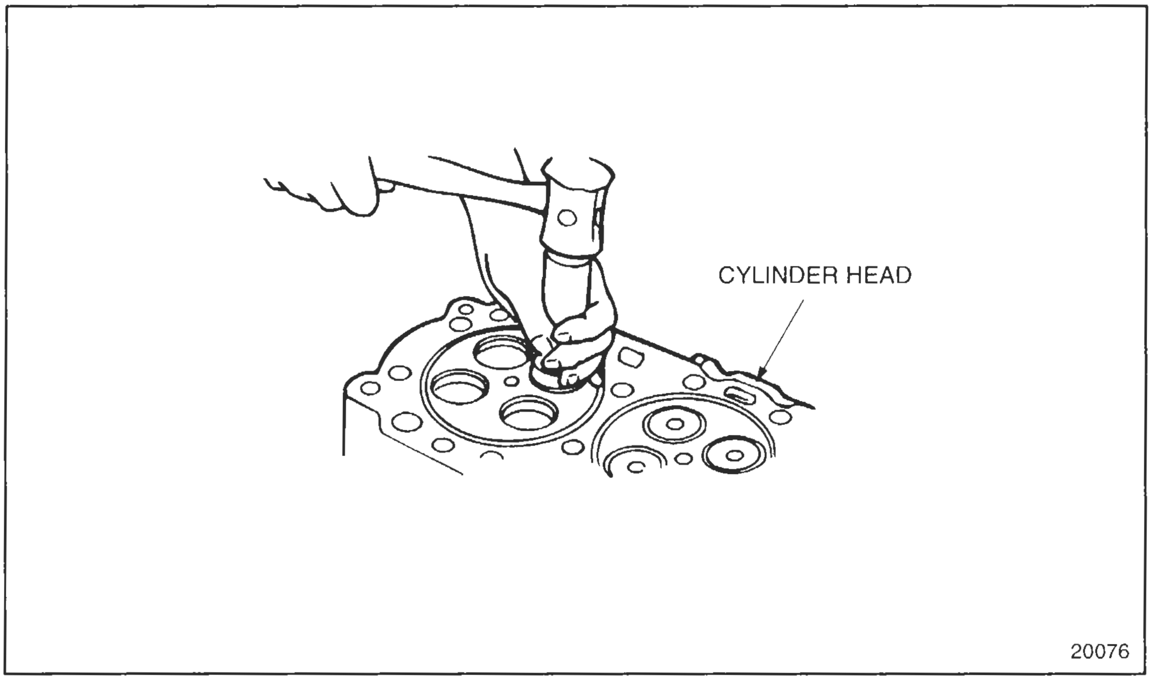


Figure 1–68 Seating Valve Seat Insert

6. Check the concentricity of valve seat with the valve guide using dial indicator, J 8165-2, and pilot, J 35623-A. See Figure 1-69.

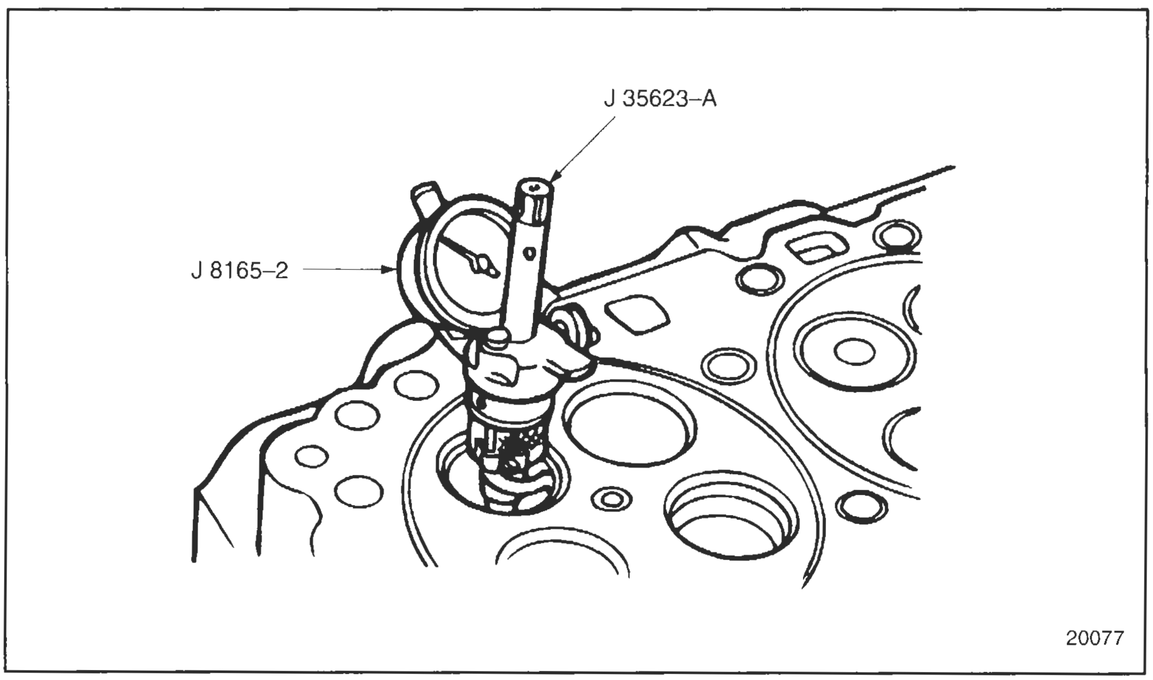


Figure 1–69 Check Valve Seat Concentricity

7. If the concentricity is not within 0.05 mm (.002 in.), grind the seat only enough to true it up, being sure to lightly grind a full 360°.

Valve seat insert grinding should be limited to light clean-up or concentricity trueing. For a fine, accurate finish, the eccentric grinding method using tool J 7040-A is recommended, because the grinding wheel contacts the insert at only one point at any time, and a micrometer feed permits controlled fine adjustment. Seats must be ground to a 31° angle. See Figure 1-70.

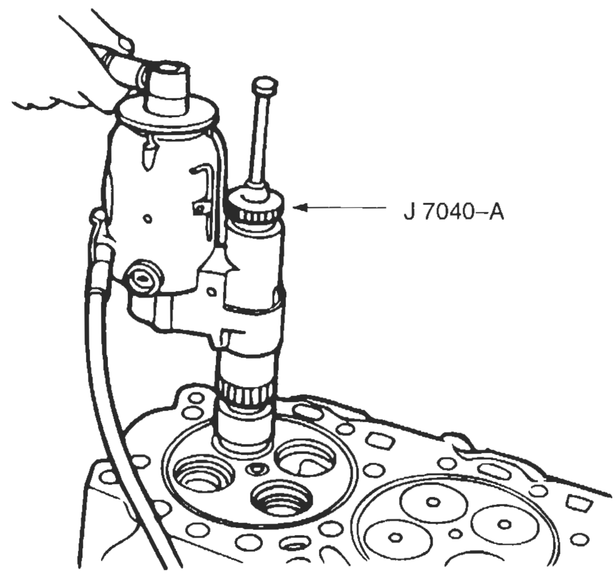


Figure 1-70 Grinding Valve Seat Insert

The valve head recess depth from the firedeck is increased by valve and/or insert grinding. It should be checked with a sled gage, J 22273–01 (or equivalent). See Figure 1–71.

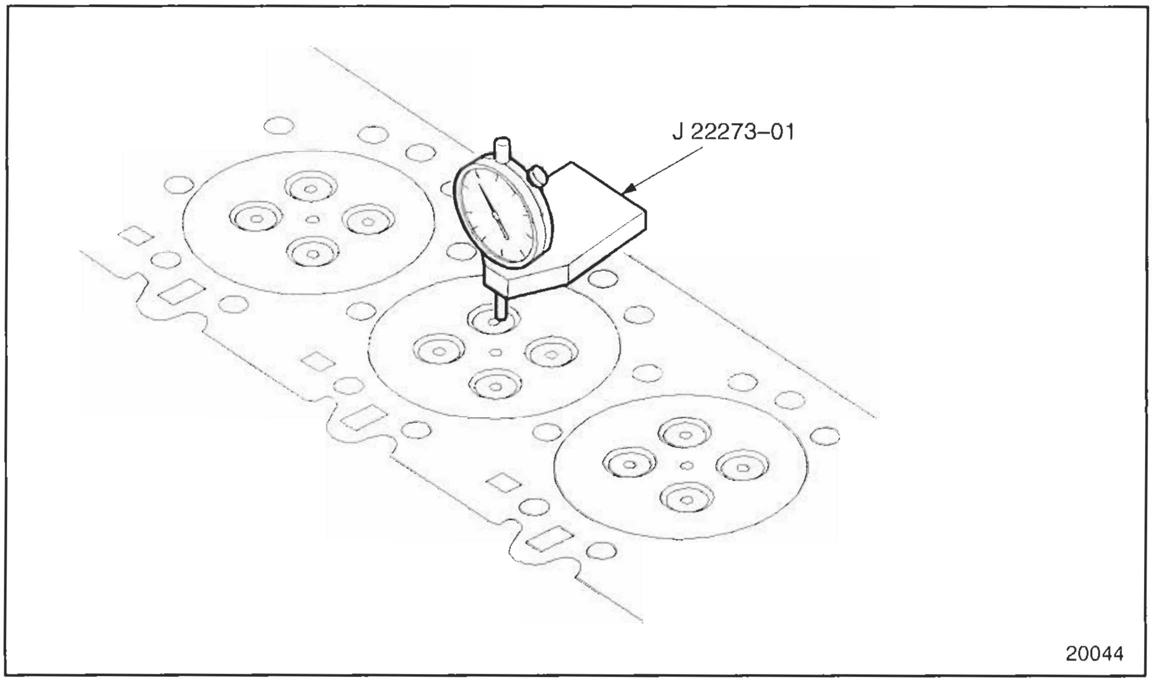


Figure 1–71 Measuring Valve Head Recess Depth

If not between 1.4 to 1.8 mm (.055–.070 in.), the valve and seat must be replaced.

After light clean–up, thoroughly clean the valve seat with fuel oil and blow dry with compressed air. Check seat–to–valve face contact by applying a light coat of Prussian Blue (or equivalent) to the valve seat land. Insert the valve in the guide and "bounce" the head on the seat insert without rotating the valve. A full 360° contact line should appear approximately centered on the valve face.

1.4.7 Valve Guide Installation

Perform the following steps for valve guide installation:

1. Start the chamfered end of the valve guide into the cylinder head from the top. See Figure 1-72.

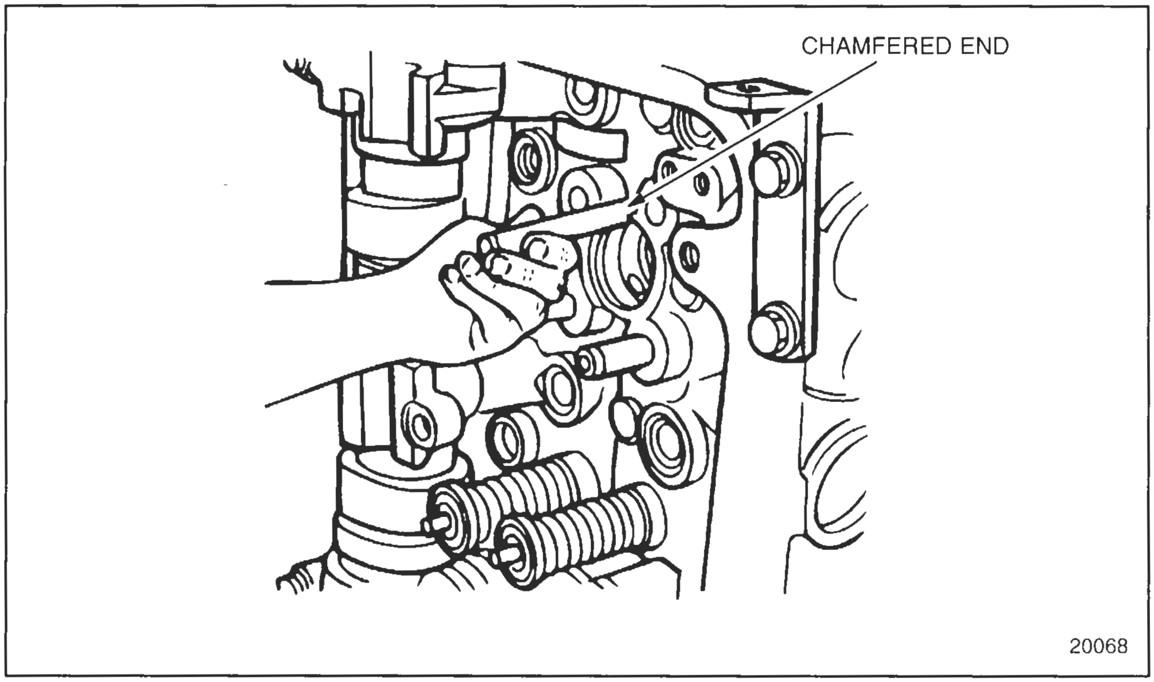


Figure 1-72 Valve Guide Installation

2. Insert the driver into an air chisel. Insert the driver into the valve guide limiting sleeve and install this assembly over the valve guide. Drive the guide into the cylinder head using valve stem seal installer, J 35599 until the installer bottoms in the limiting sleeve. See Figure 1–73.

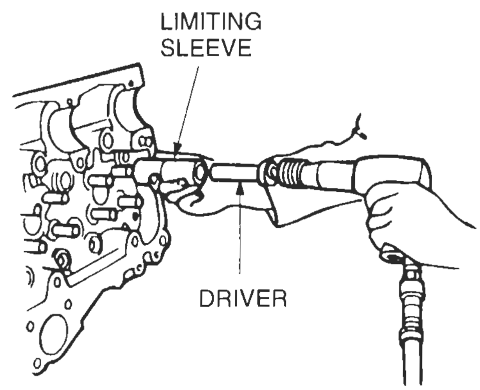


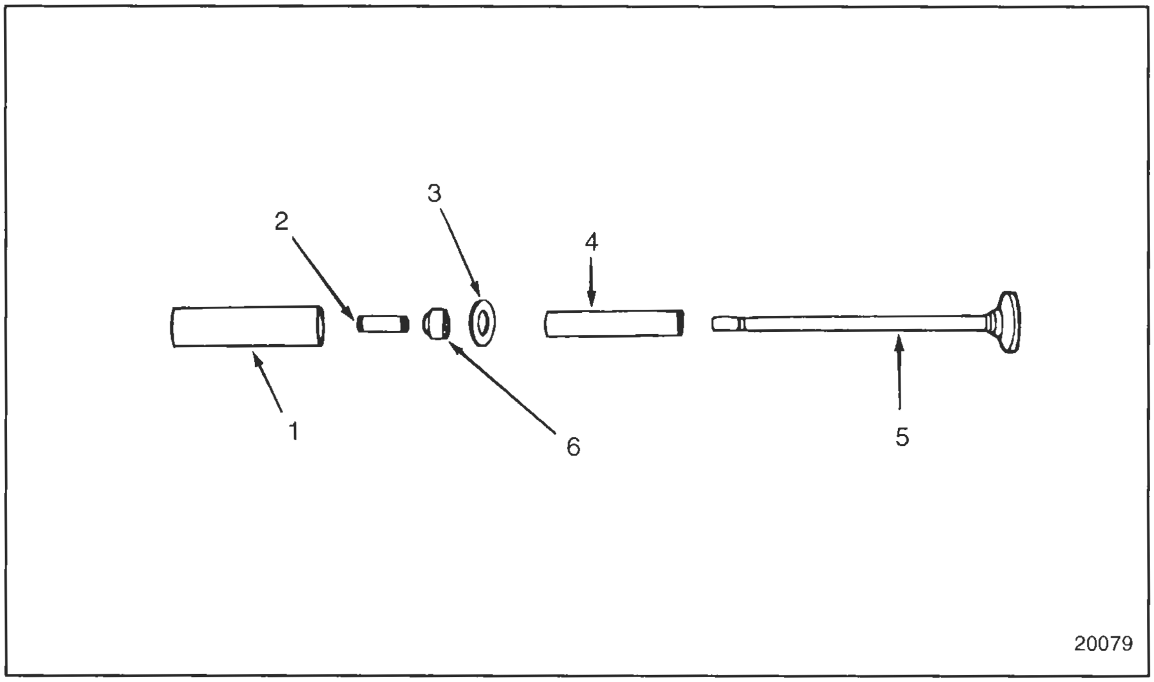
Figure 1–73 Valve Guide Installation

3. Properly used, the installer ensures the correct protrusion of the valve guide from the cylinder head of 37.75 mm (1.486 in.).

1.4.8 Valve Spring, Seal and Rotator Installation

Perform the following steps for valve installation:

1. Position the cylinder head vertically on the overhaul stand. Lubricate the valve stems with clean engine lubricating oil and slide them into their respective valve guides and against the valve seats. If reusing valves, install them to their original positions.
2. Install the valve spring seat over the valve guide. Install the valve stem oil seals using valve stem oil seal installation tools. See Figure 1–74.



1. Valve Stem Seal Installer
2. Oil Seal Protector Cap
3. Valve Spring Seat
4. Valve Guide
5. Valve
6. Valve Stem Oil Seal

Figure 1–74 Valve Stem Oil Seal Installation Tools

3. Check the length of the plastic seal protector cap relative to the lock groove on the valve stem. See Figure 1–75.

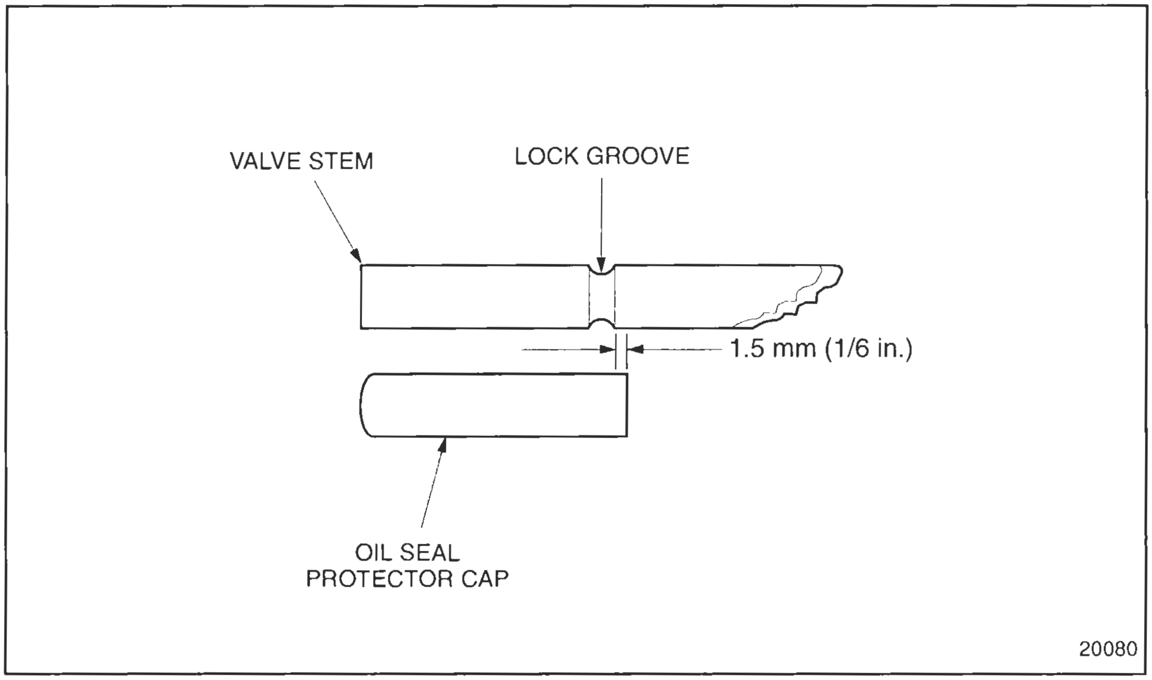


Figure 1–75 Oil Seal Protection Cap Sizing

[a] If the seal protector cap extends more than 1.5 mm (1/16 in.) beyond the groove, trim off the excess length of the cap.

4. Install the cap over the valve stem. See Figure 1–76.

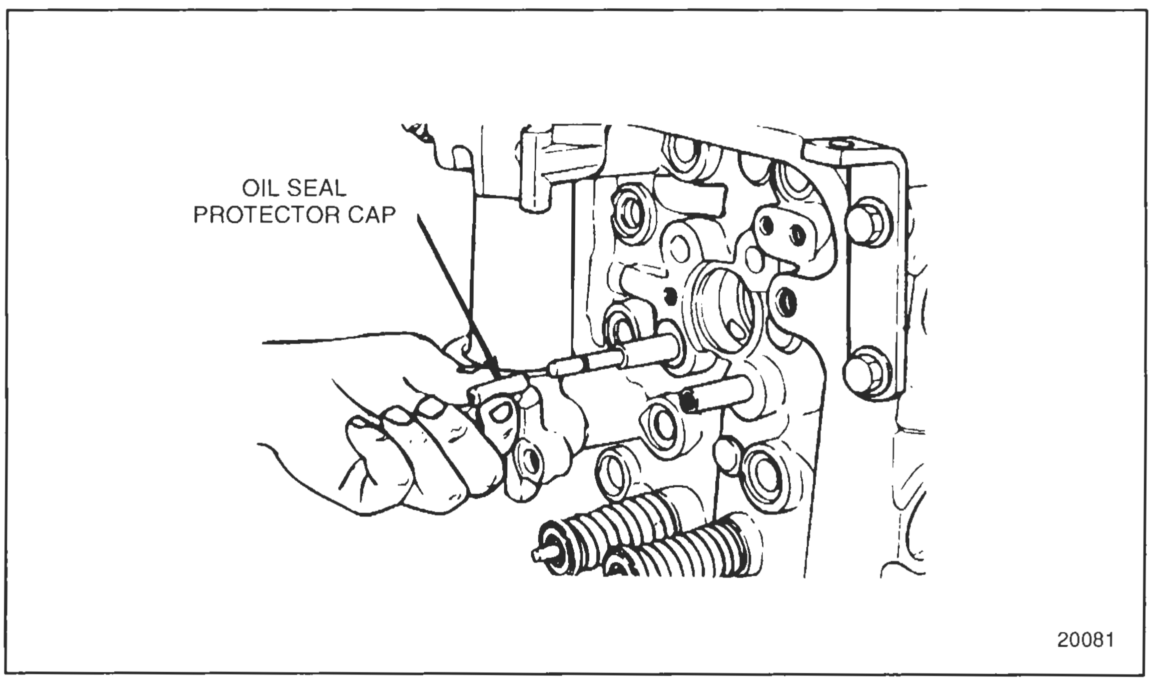


Figure 1–76 Oil Seal Protection Cap Installation

NOTICE:
Be sure that all valve spring seats have been installed before the valve stem seal is installed.

5. The valve stem oil seal may be installed with or without oil. Push the seal over the protector. See Figure 1–77.

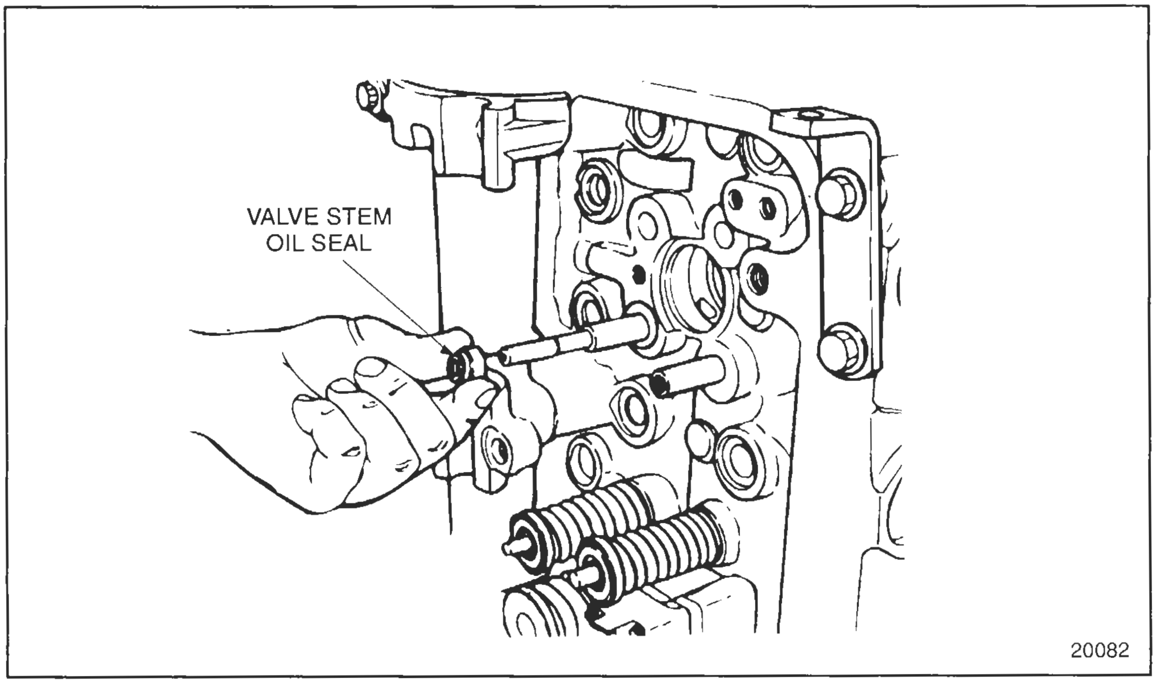


Figure 1–77 Valve Stem Oil Seal Installation

6. Push the seal down on the valve stem using the seal installer, J 39109 while holding the valve head against the sea. See Figure 1–78.

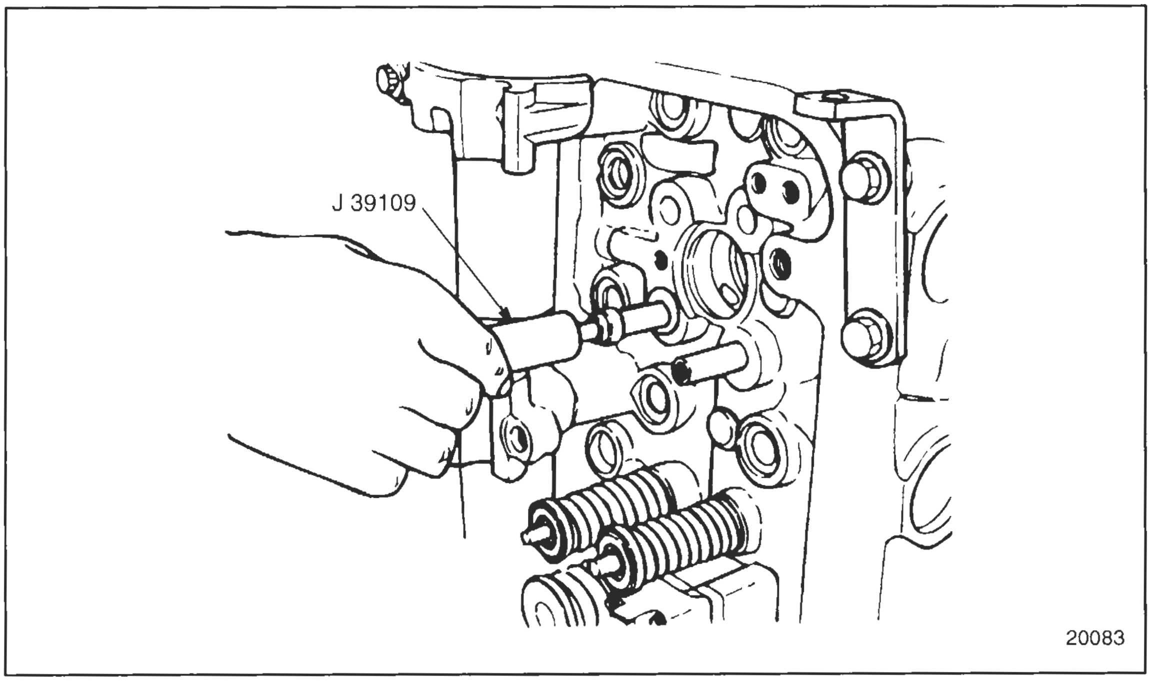
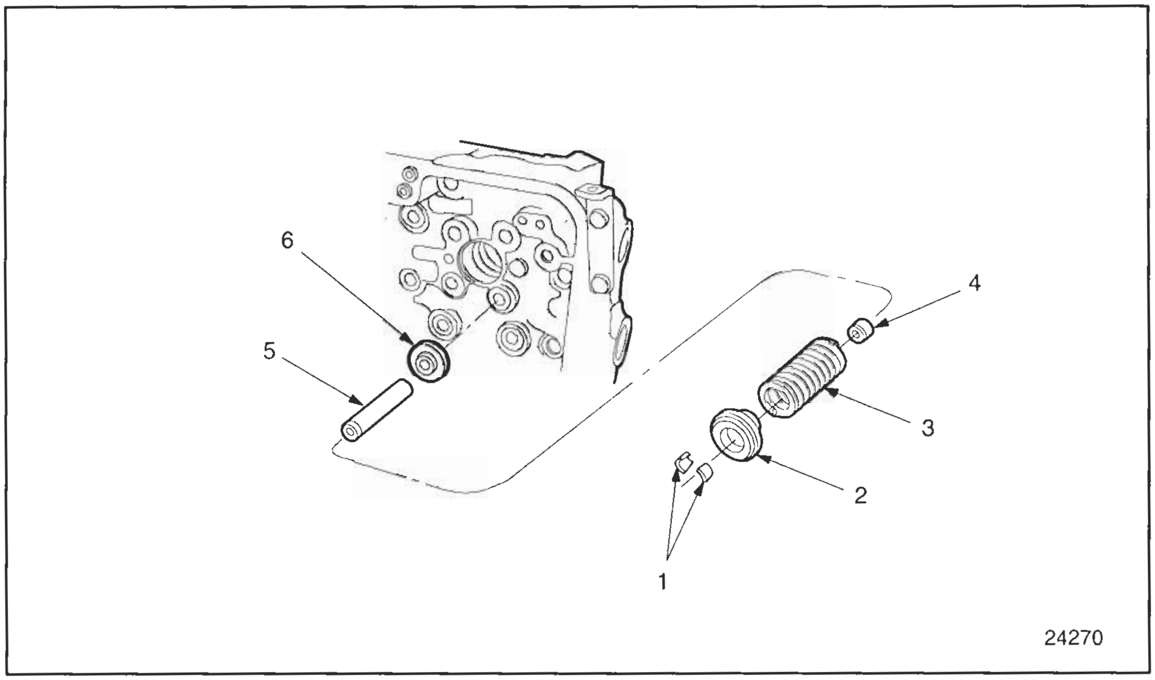


Figure 1–78 Valve Stem Oil Seal Installer

7. When the installer tool contacts the cylinder head, the seal is correctly positioned. Be sure the installer is square against the cylinder head. Remove the seal installer and protector cap.
8. Install the valve spring and rotator. See Figure 1–79. If reusing parts, install them to their original positions.



1. Valve Key Locks
2. Valve Rotator
3. Valve Spring
4. Valve Stem Oil Seal
5. Valve Guide
6. Valve Spring Seat

Figure 1–79 Valve Spring and Related Parts

NOTE:
Always install new valve key locks when installing valves.

9. Using the valve spring compressor tool, J 8062–1, compress the valve spring only as much as required to install the valve locks. After installing the valve locks, rap the end of the valve stem sharply with a plastic mallet to seat the valve locks.

NOTE:
Be sure the valve rotator is properly centered and aligned to avoid scoring the valve stem. Do not compress the spring any more than necessary to install the locks, to avoid damaging the oil seal.

10. After all of the valves are installed, check the spring opening pressure on each valve using spring load gage, J 25076–B (or equivalent). See Figure 1–80.

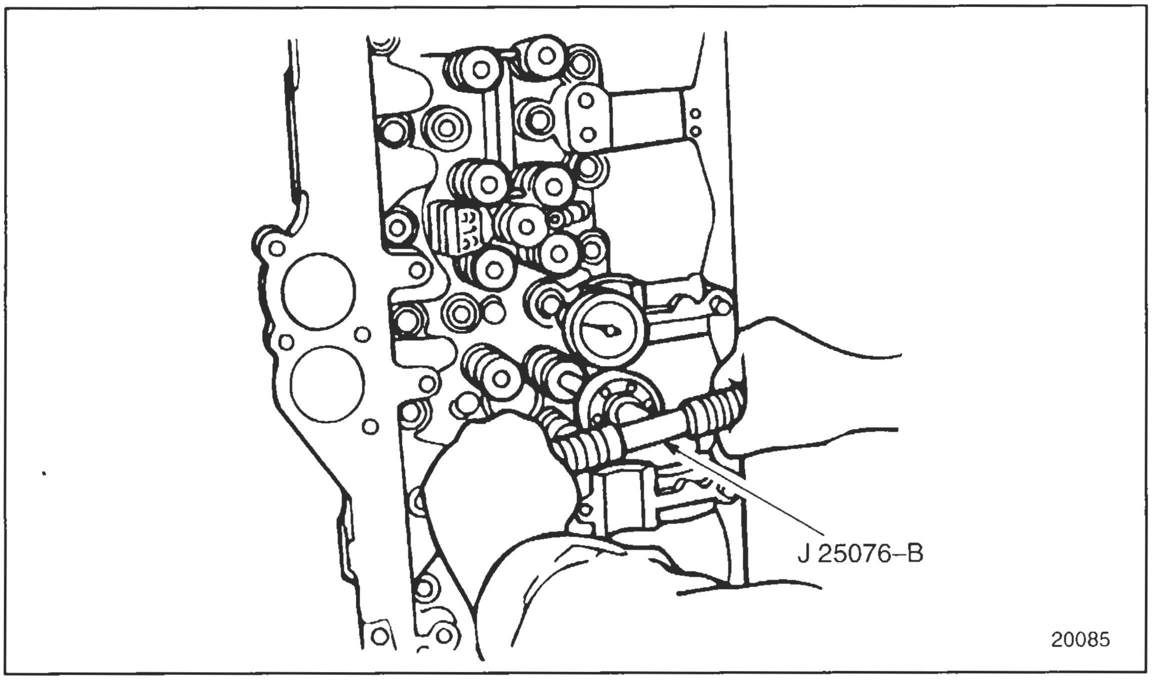


Figure 1–80 Checking Valve Spring Load

11. Note the gage reading when the valve just starts to unseat. The force required to unseat the valve must not be less than 290 N (65 lb).
12. Remove the cylinder head from the overhaul stand and install it on the engine. Refer to section 1.2.5.
13. Install the camshaft and rocker arm assemblies. Lightly lubricate the overhead assemblies with clean engine oil. Refer to section 1.22.5.
14. If the engine is equipped with a Jake Brake, install the brake. Refer to section 1.29.3.
15. Adjust the valve clearance and injector timing. Refer to section 12.2.
16. If the engine is equipped with a Jake Brake, lash the brake. Refer to section 1.29.
17. Install any other components that were removed.
18. Fill the engine crankcase, refer to section 13.5.1, with the proper lubricant. Refer to section 5.2.1 and refer to section 5.2.1.1 for proper lubricant.
19. Close any drain cocks that were opened and fill the cooling system. Refer to section 13.5.4. Purge the air from the system using the vent in the thermostat housing. Complete filling of the cooling system is essential for proper engine operation.
20. Start the engine and check for leaks.

1.5 ENGINE LIFTER BRACKETS

A total of three engine lifter brackets are installed on each Series 50 Engines and are utilized when removing and replacing the engine. See Figure 1–81.

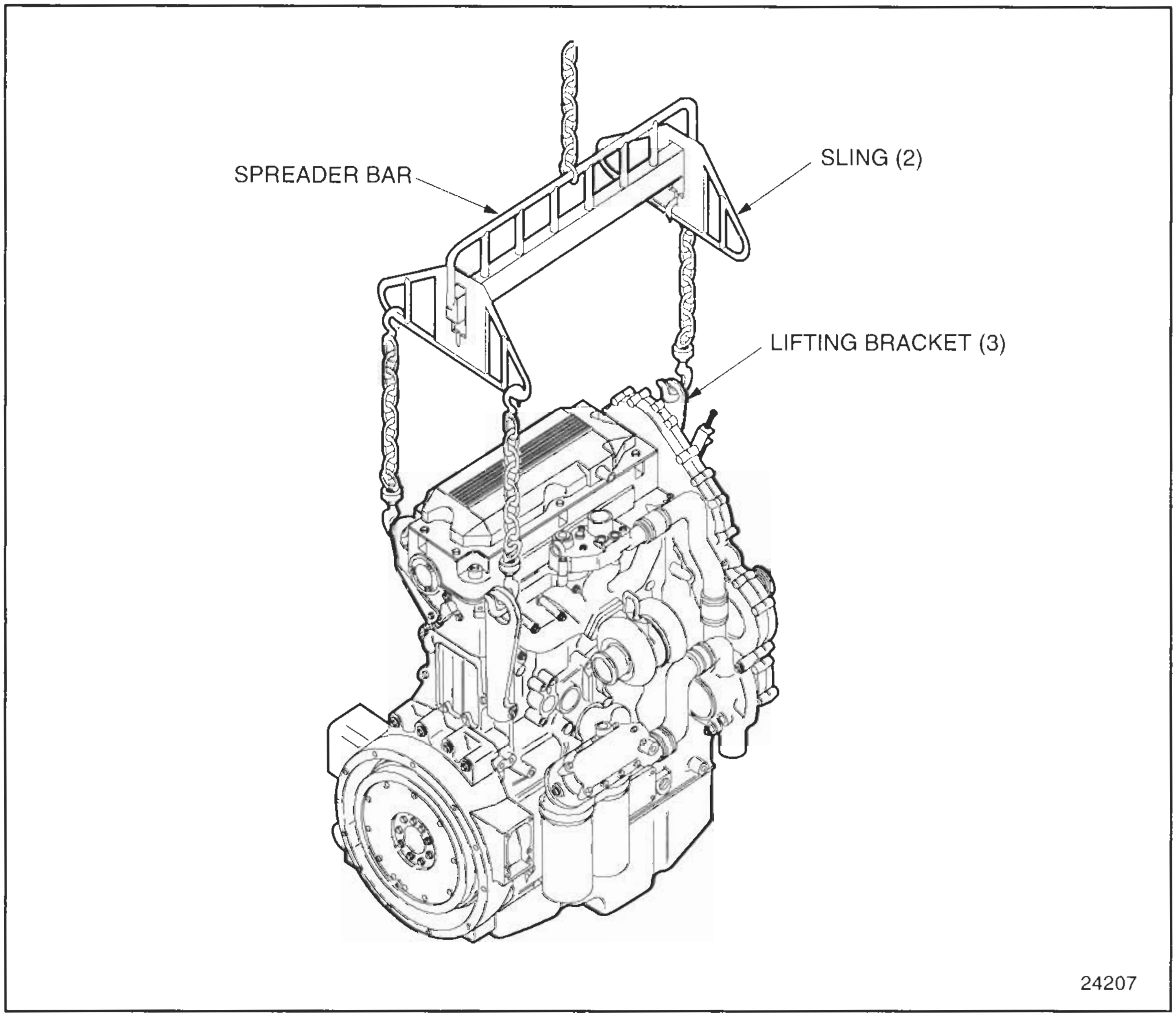


Figure 1–81 Lifting Engine

NOTICE:

To lift the engine, use a suitable lifting device. See Figure 1–81. A spreader bar should be used with a sling and adequate chain hoist when lifting any engine. The lifting device should be adjusted so the lifting hooks are vertical to prevent bending the engine lift brackets. To ensure proper weight distribution, all three engine lift brackets provided must be used in lifting the engine. Be sure the spreader bar is adequate to prevent lifter brackets from contacting the engine rocker cover and causing damage.

A lifter bracket should always be reinstalled whenever removal is necessary. See Figure 1–82.

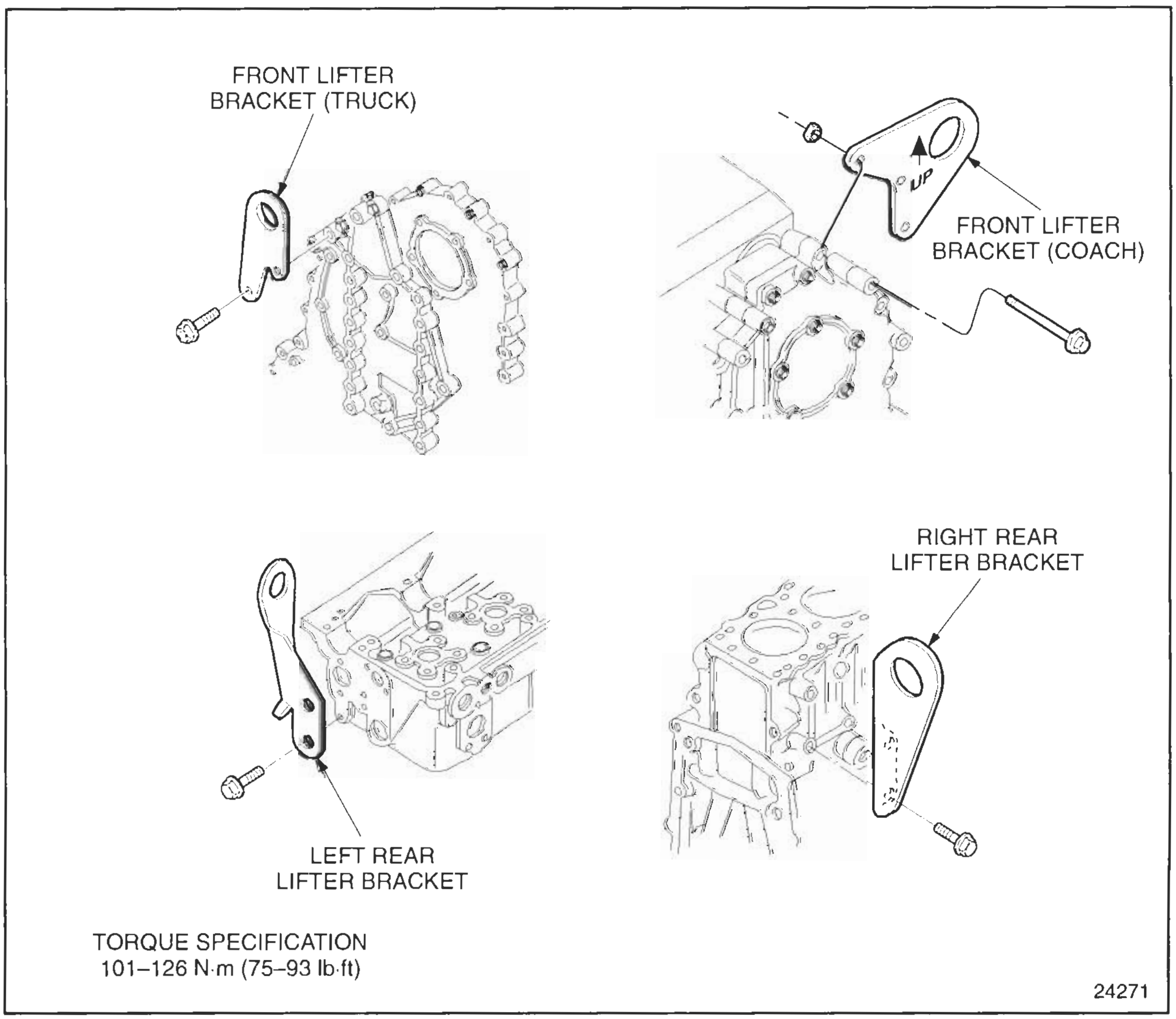


Figure 1–82 Engine Lifter Brackets

1.5.1 Repair or Replacement of the Lifter Bracket

To determine if repair is possible or replacement is necessary perform the following procedure. See Figure 1-83.

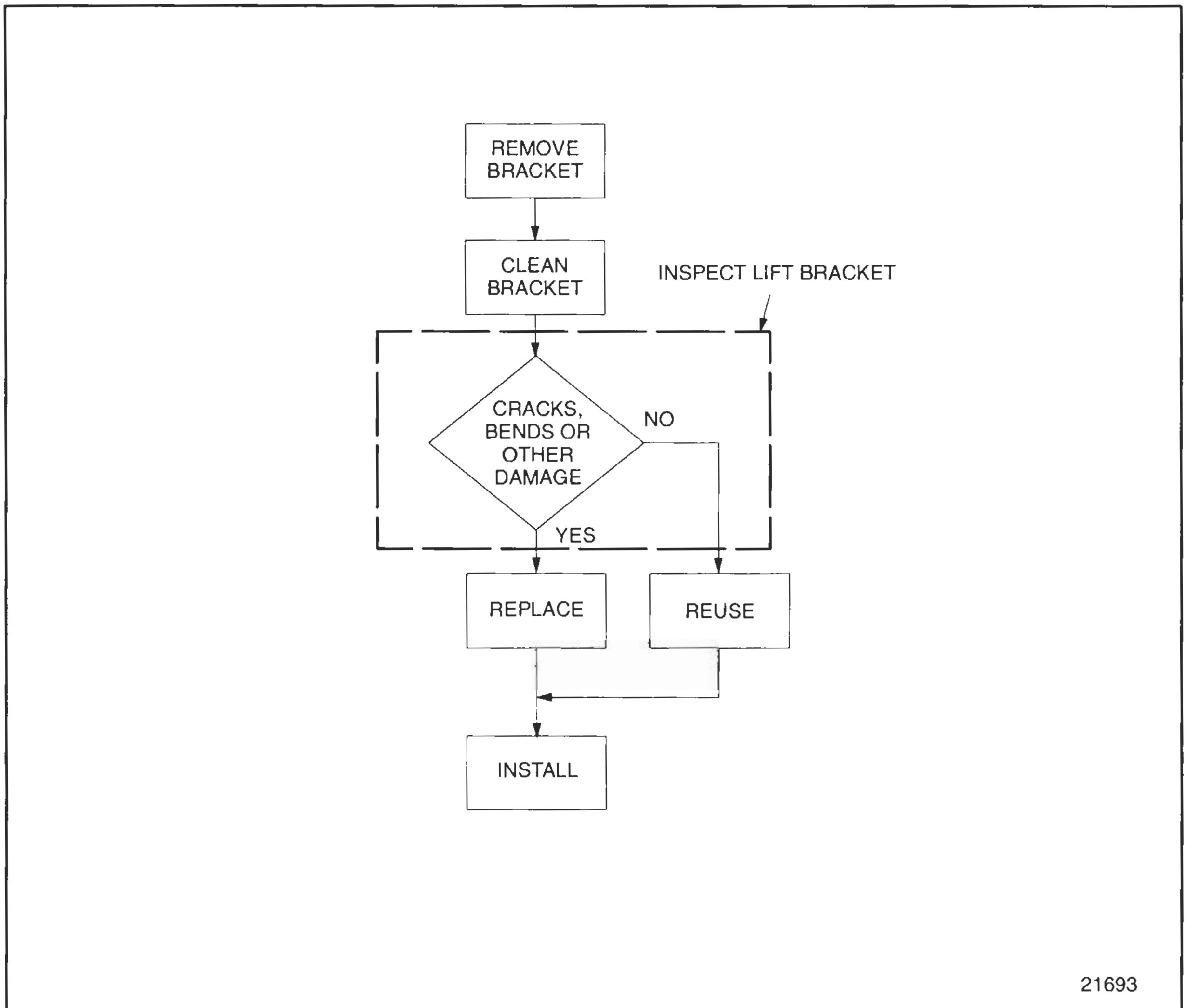


Figure 1-83 Flowchart for Repair or Replacement of Lifter Bracket

1.5.2 Removal and Cleaning of Lifter Bracket

Perform the following steps for lifter bracket removal:

1. Remove the bolts securing the lifter bracket to the engine.

1.5.2.1 Inspection of Lifter Bracket

Perform the following for lifter bracket inspection:

CAUTION:
A bracket that is bent or otherwise damaged may cause personal injury or component damage when the engine is being removed/installed from the equipment. Replace any damaged or bent brackets before attempting engine removal/installation.

1. Inspect the lifter brackets for cracks, bending or other damage.
2. Replace the bracket if any of these conditions exist.

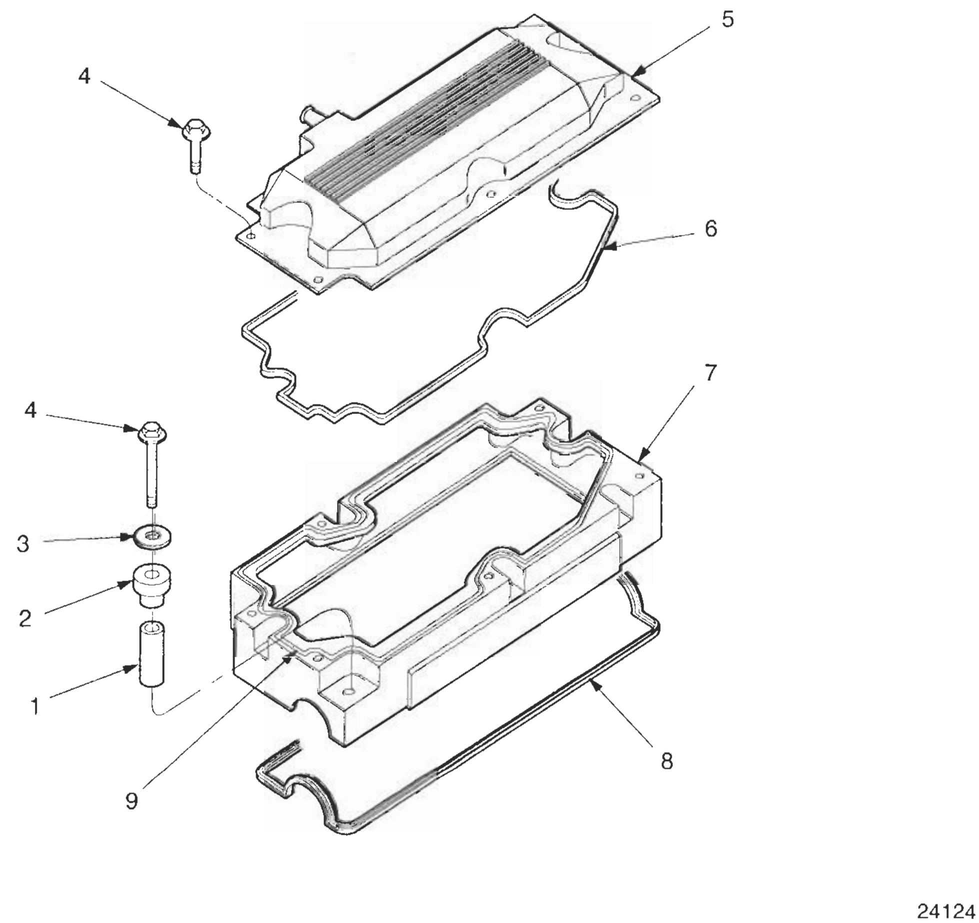
1.5.3 Installation of Lifter Bracket

Perform the following steps for lifter bracket installation:

1. Install the bracket to the engine. Tighten the mounting bolts to 101–126 N·m (75–93 lb·ft) torque.
2. Follow the fan support bracket installation instructions, torque specifications, and tightening sequence in "Installation of Gear Case Cover;" refer to section 1.10.3.

1.6 ROCKER COVER

The Series 50 Engines uses a two-piece rocker cover is constructed of cast aluminum. The top piece or cap is held in place by six bolts and is removable for access to the valve, engine brake and fuel injector adjusting mechanisms. See Figure 1-84.



1. Limiting Sleeve
2. Isolator
3. Washer
4. Bolt
5. Rocker Cover Cap
6. Rocker Cover Gasket
7. Rocker Cover Base
8. Isolator Rim Seal
9. Diamond-Shaped Seal

Figure 1-84 Two-piece Rocker Cover

A one-piece diamond-shaped perimeter seal is located in a groove in the rocker cover base and seals the cap to the base.

Two caps are available with the Series 50 Engines. One is for use with a Jake Brake, and one without a Jake Brake.

The rocker cover base is attached to the cylinder head using eight assemblies consisting of a bolt, limiter sleeve, isolator and flat washer. All rocker covers use a silicone rim seal, seated in a groove around the edge of the rocker cover to provide an effective oil seal. The two-piece design rocker cover has a provision for a crankcase ventilation breather which is used when the gear case filler breather is not present.

1.6.1 Repair or Replacement of Rocker Cover

To determine if repair is possible or replacement is necessary perform the following procedure. See Figure 1-85.

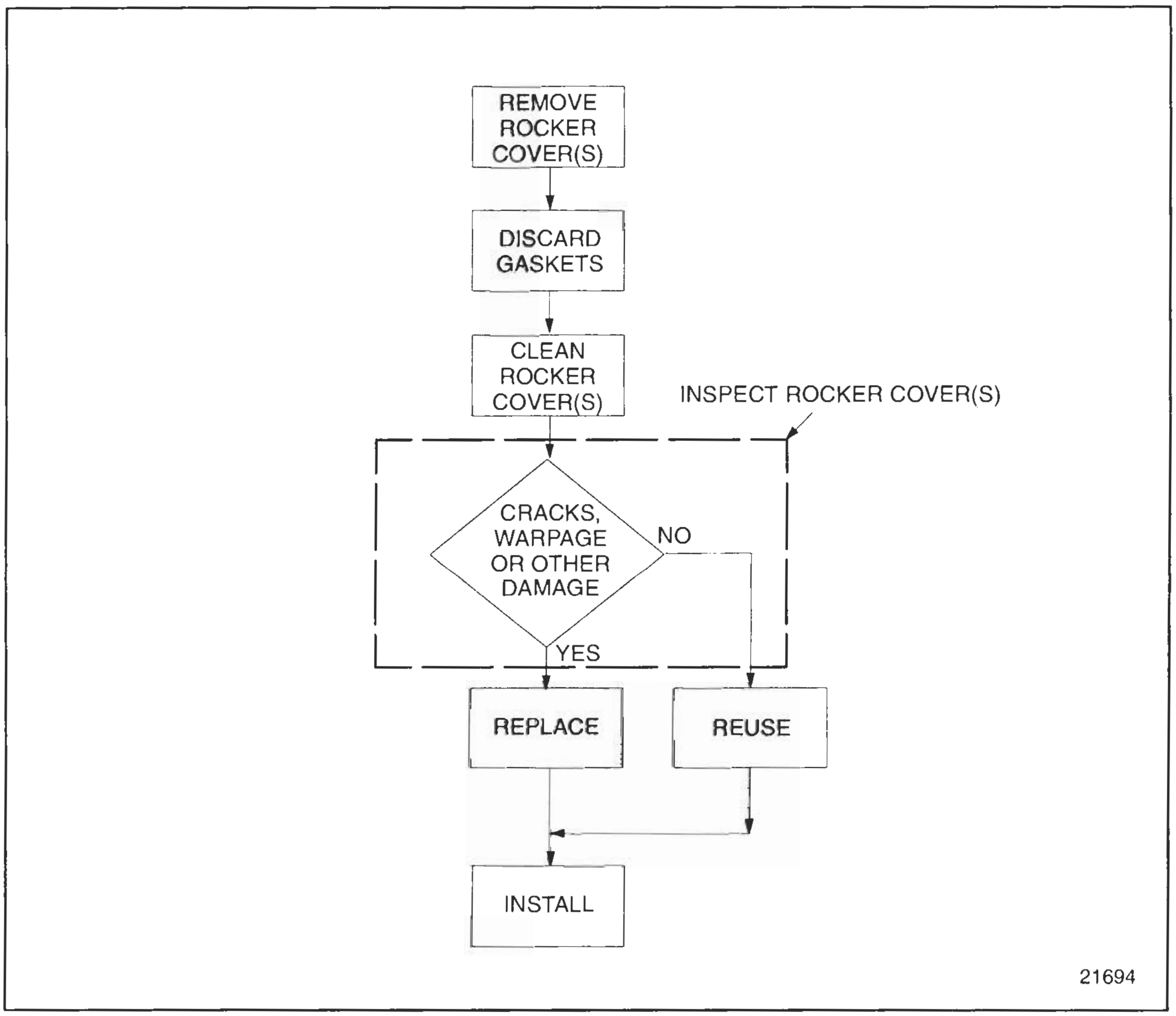


Figure 1-85 Flowchart for Repair or Replacement of Rocker Cover

1.6.2 Removal and Cleaning of Two–piece Rocker Cover

Preclean the rocker cover, especially around its seat on the head, and in the attaching bolt recesses, to keep dirt and debris out of the valve gear chamber.

To remove the two–piece rocker cover:

1. Remove the six screws that attach the rocker cover cap to the base.
2. Lift the cap off the base.
3. Loosen and remove the eight bolt/isolator assemblies that attach the base to the cylinder head.
4. Lift the base straight up off the cylinder head.

1.6.3 Disassembly of Two–piece Rocker Cover

Disassemble the two–piece rocker cover as follows:

1. Disengage the clip that holds the crankcase vent breather element in the rocker cover by pressing the center of the spring steel retaining clip outward and removing the straight end.
2. Rotate the clip upward to remove the curved end.
3. Remove the wire mesh element.

1.6.3.1 Inspection of Two–piece Rocker Cover

To inspect the two–piece low profile valve cover cap which had a removable breather housing:

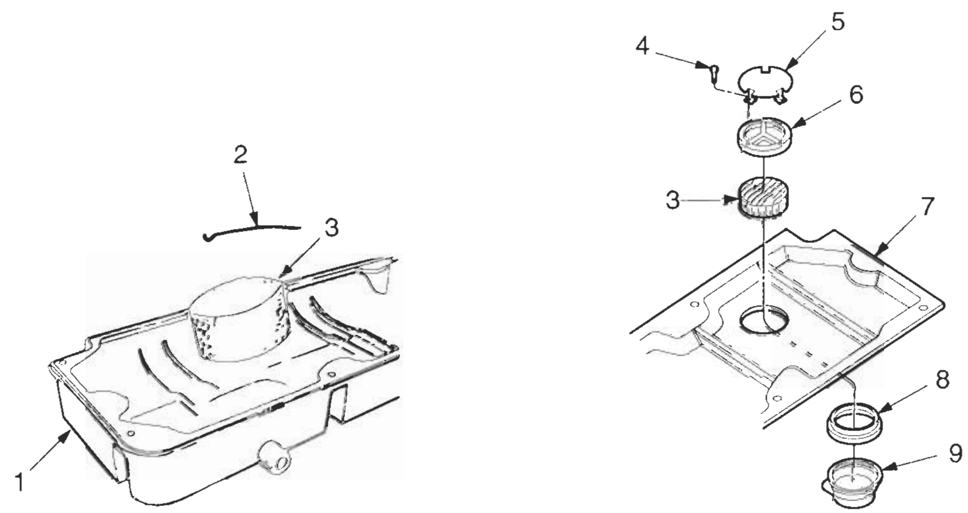
1. Remove the three screws and retainer that retains the breather housing.
2. Remove the breather housing, seal, and wire mesh element.
3. Wash the components in clean fuel oil.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

4. Blow dry with compressed air.

5. Reassemble breather housing to rocker cover cap. See Figure 1–86. Tighten the screws to 2.5 N·m (22 lb·in.) torque.



1. Two–piece Rocker Cover
2. Retainer Clip
3. Wire Mesh Element
4. Screw
5. Retainer Cover
6. Retainer
7. Two–piece Low Profile Rocker Cover Cap
8. Seal
9. Breather Housing

Figure 1–86 Crankcase Vent Breather

1.6.4 Pre–installation of Rocker Cover

Perform the following steps prior to installing the rocker cover:

NOTE:
Be sure the rocker cover grooves and the seals are clean, free of oil and dry.

1. Install the rocker cover gasket in corners of the camshaft cap section (arch at each end of the rocker cover) first.
2. Install the cam cap section, starting in the center, by pushing the seal into the groove at the top of the arch. Then install each section at its halfway point. Seat the gasket completely around the arch. Be sure the corners are still firmly seated after the arch is completed. They should present a square corner parallel to the rocker cover rail. Repeat this procedure for the cam cap section on the other end. See Figure 1–87.

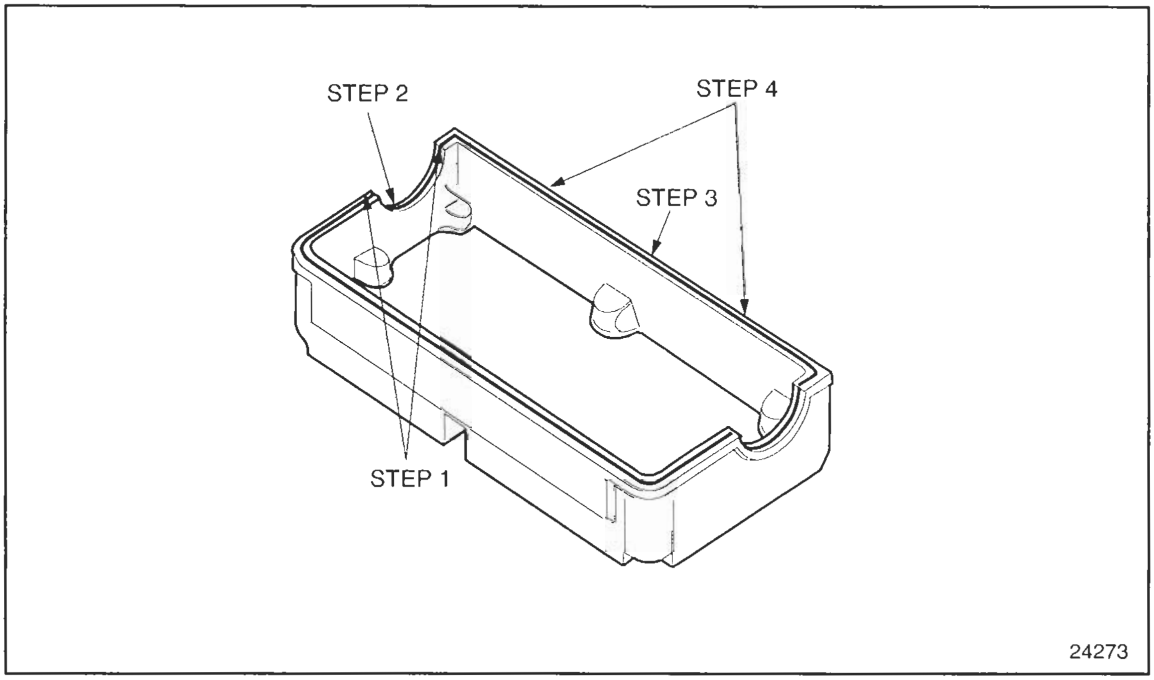


Figure 1–87 Rocker Cover Gasket Installation

3. Install the long runs of the gasket starting in the center, by pushing the seal into the groove.
4. Then install the rail portion at each halfway point. Repeat this procedure for the other rail portion. Make sure the seal is completely seated all the way around the rocker cover.

NOTE:
The corners must be cleaned prior to RTV installation for best results.

5. Apply a small 3.0 mm (3/16 in.) fillet of RTV in the corners formed by the rear camshaft cap and the head, where the cover seal contacts. Repeat this procedure for the corners formed by the front camshaft cap and the head. See Figure 1–88.

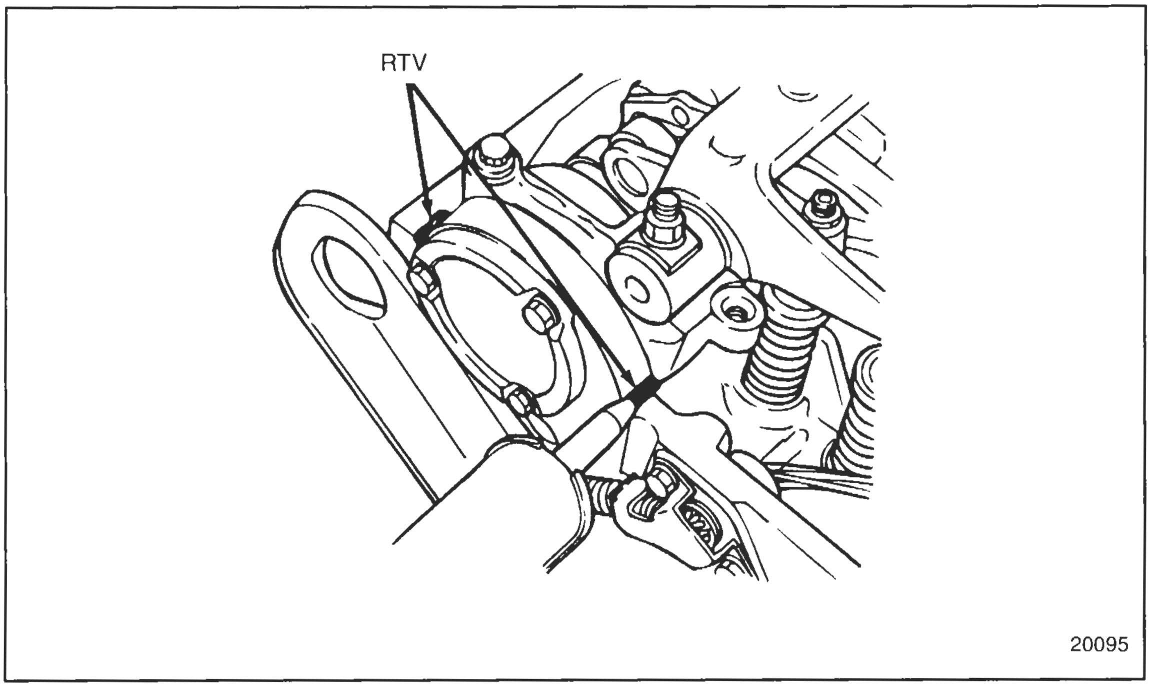


Figure 1–88 RTV Installation

1.6.5 Installation of Two–piece Rocker Covers

Install the two–piece rocker cover as follows:

1. Position the rocker cover base on the cylinder head.
2. Lubricate the valve cover limiting sleeves with clean silicone spray. Insert the sleeves into the isolators until the end of the sleeve is flush with the isolator. See Figure 1–89.

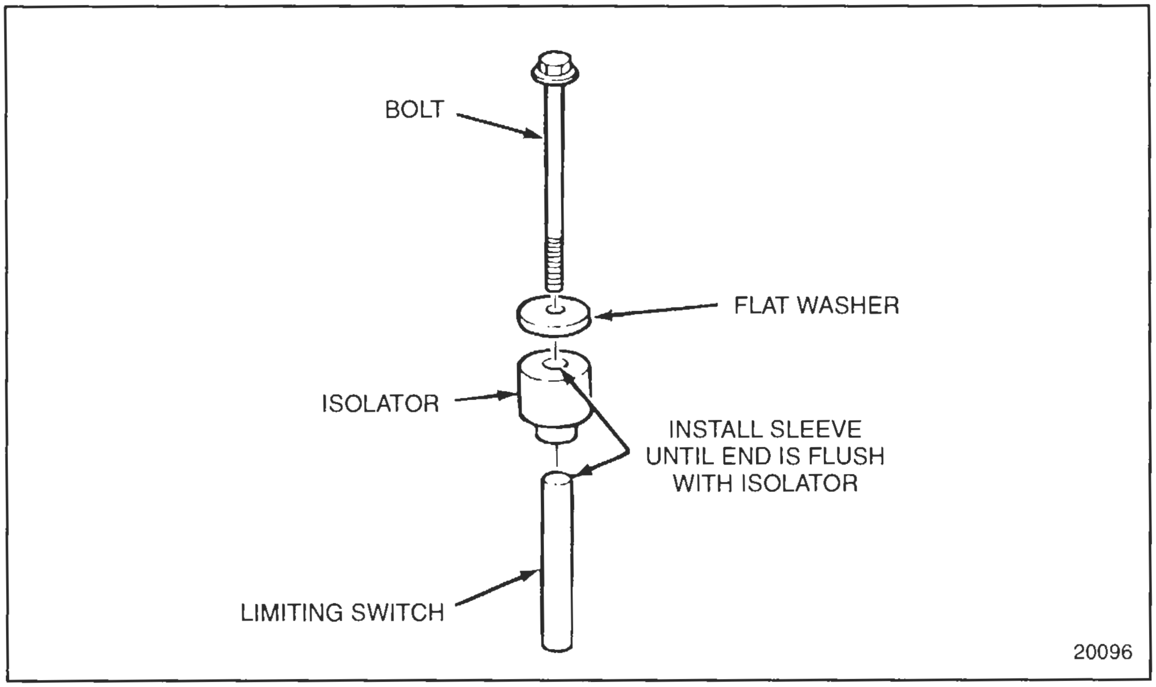


Figure 1–89 Rocker Cover Base Hold–down Hardware

3. Install the hold–down bolts, with washers installed, to the limiting sleeves.

4. Install the hold–down assemblies to the rocker cover base, and thread the bolts two–to–three threads into the cylinder head.

NOTE:
Use care when tightening the rocker cover base hold–down bolts that the injector wires do not get caught between the limiting sleeve and the cylinder head. See Figure 1–90.

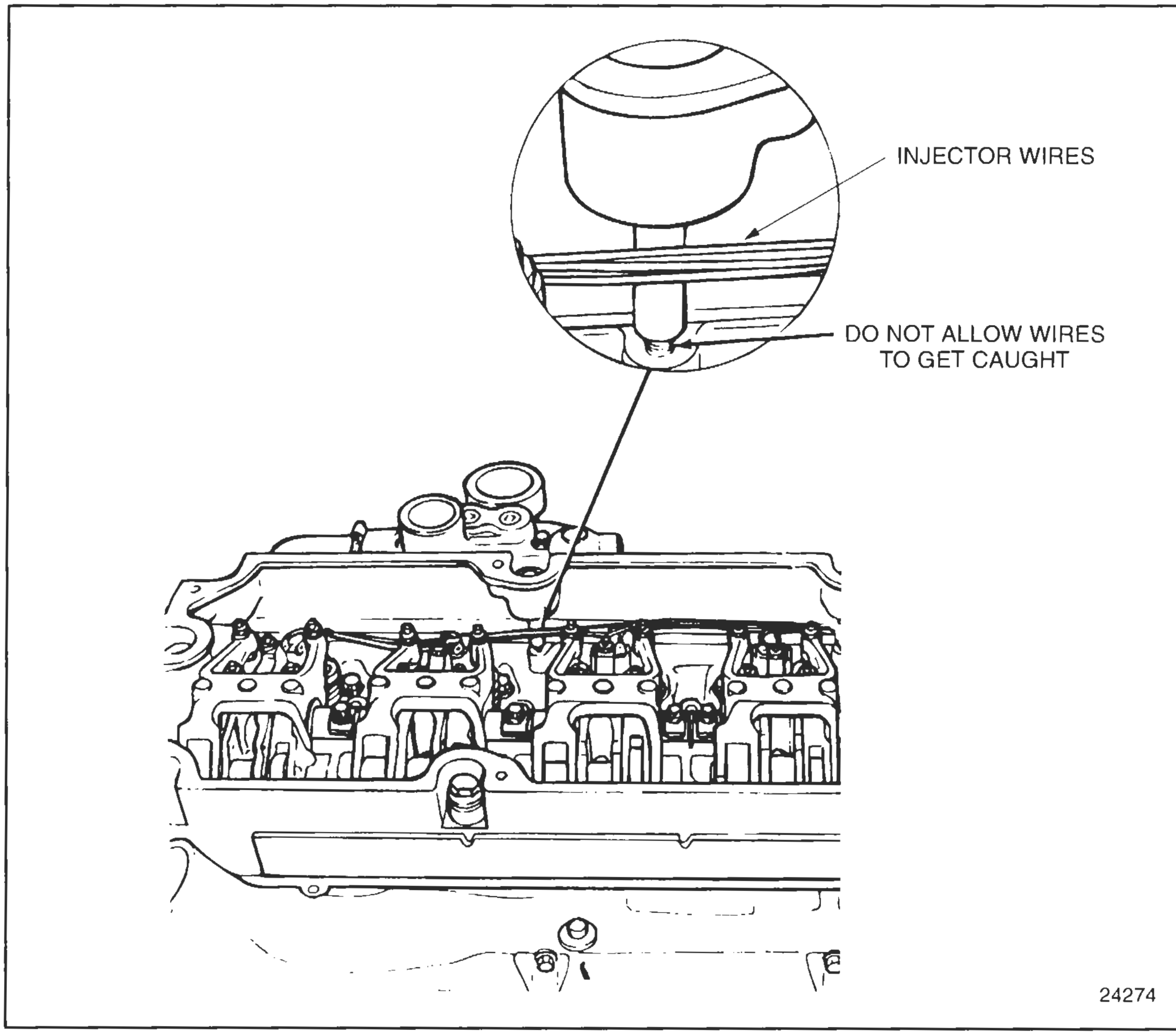


Figure 1–90 Rocker Cover Base Hold–down Bolt Installation

5. Tighten the eight rocker cover base hold-down bolts to 30–38 N·m (22–28 lb·ft) torque using the tightening sequence. See Figure 1–91. Tighten the bolts in two stages, using half-torque value first.

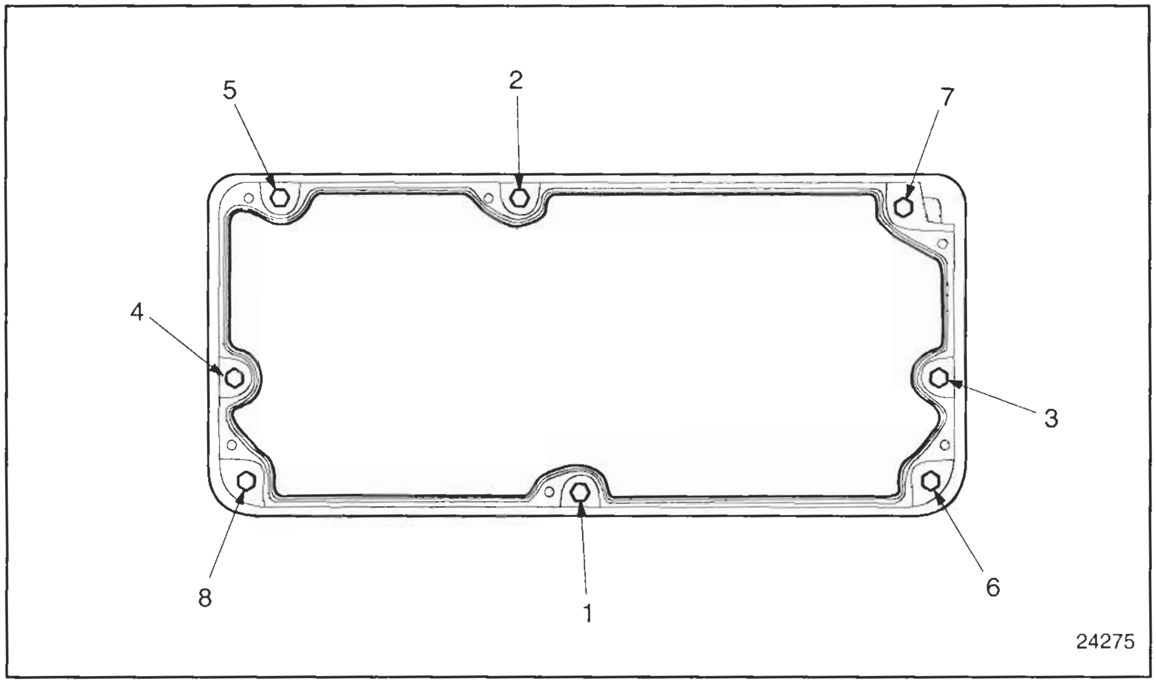


Figure 1–91 Rocker Cover Base Bolt Tightening Sequence

6. Be sure the groove in the bottom of the rocker cover base, and its mating, diamond-shaped seal are clean and dry. Install the diamond-shaped seal to the groove by pressing the seal into the groove. Use care not to stretch or twist the seal. The seal has a definite shape, and should be installed exactly as removed from the base. If the seal cannot be installed to its groove without bunching or looping, the seal is stretched and must be replaced. The same procedure applies to the intermediate cover diamond seal installation.

7. Install the rocker cover cap to the base. Install the six bolts that attach the cap to the base, and tighten to 22–25 N·m (16–18 lb·ft) torque using the torque sequence. See Figure 1–92. Tighten the bolts in two stages, using half–torque value first. The same procedure applies to the intermediate cover installation.

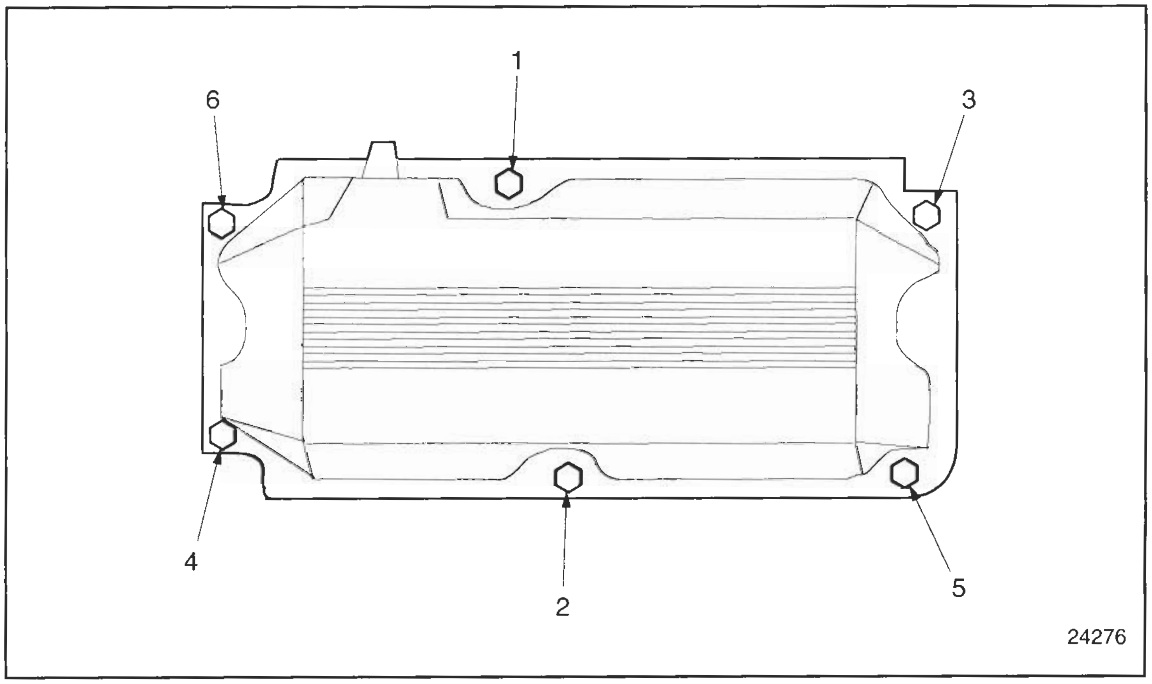


Figure 1–92 Rocker Cover Bolt Cap Tightening Sequence

8. Install any other parts that were removed for this procedure.
9. Start the engine and check for leaks.

1.7 CRANKSHAFT

The crankshaft is a one-piece forging of chrome-alloy steel, heat-treated to ensure strength and durability. See Figure 1-93.

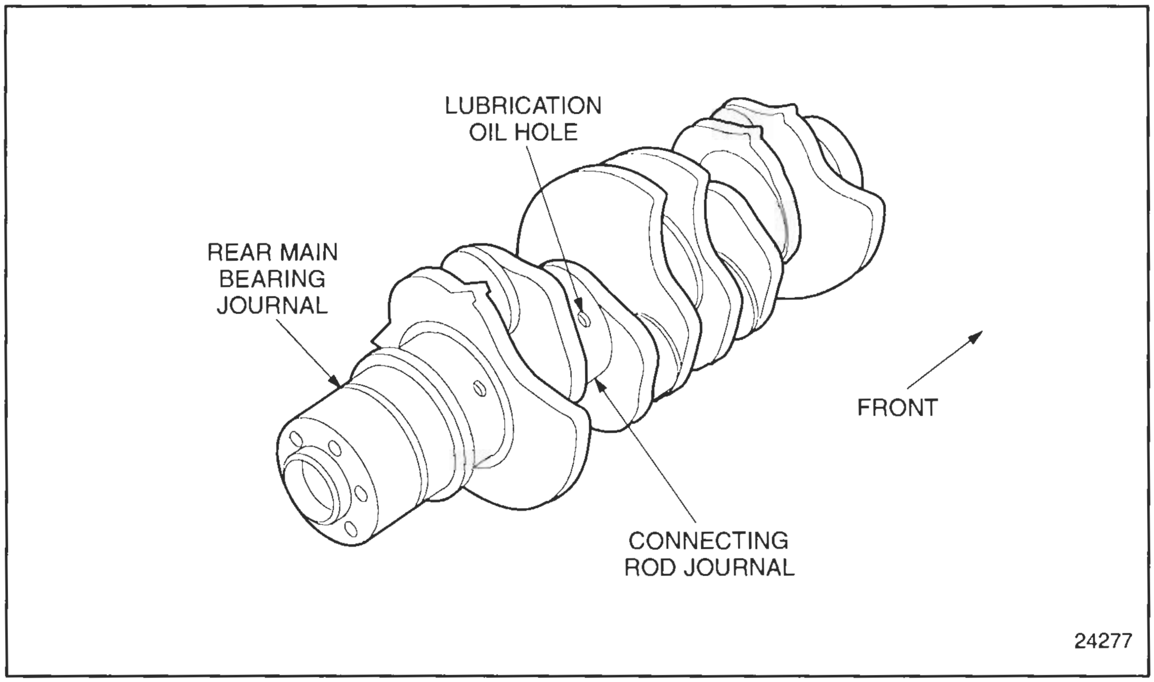


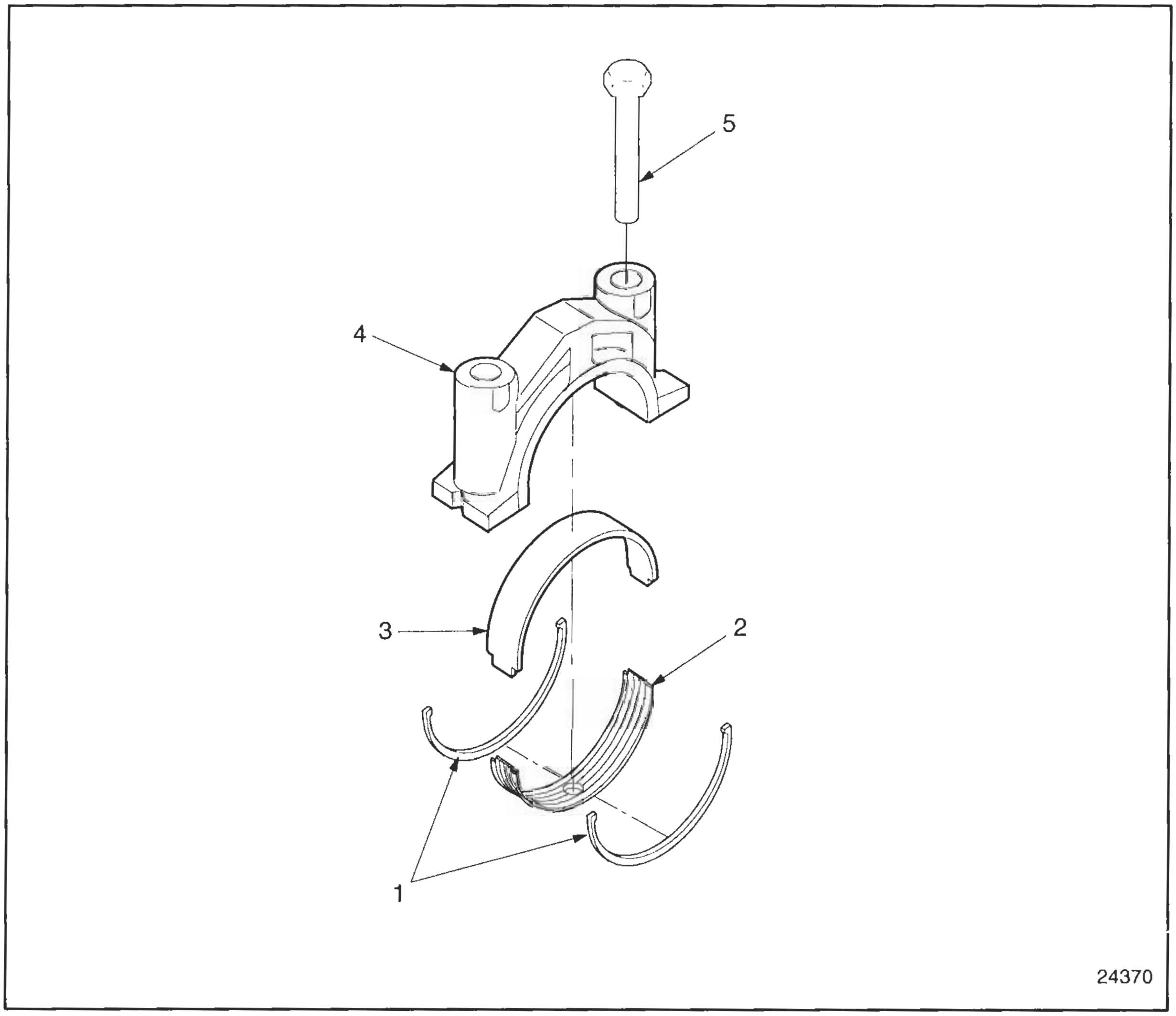
Figure 1-93 Crankshaft

The main and connecting rod bearing journal surfaces and fillets are induction hardened.

Complete static and dynamic balance of the crankshaft has been achieved by counter-weights incorporated in the crankshaft.

Crankshafts have a twelve-bolt mounting pattern on the front.

The crankshaft end play is controlled by thrust washers located at the No. 4 main bearing cap and saddle of the engine. See Figure 1–94.



1. Upper Thrust Washer
2. Upper No. 4 Bearing
3. Lower No. 1–5 Bearing Shell
4. No. 4 Main Cap
5. Bolt

Figure 1–94 Crankshaft Thrust Bearing Detail

This design makes use of thrust washers in the upper positions only.

Oversize thrust washers are available to correct for excessive end play.

This design does not use the indexing dowels.

Full pressure lubrication to all connecting rod and main bearings is provided by drilled passages within the crankshaft and cylinder block. See Figure 1-95.

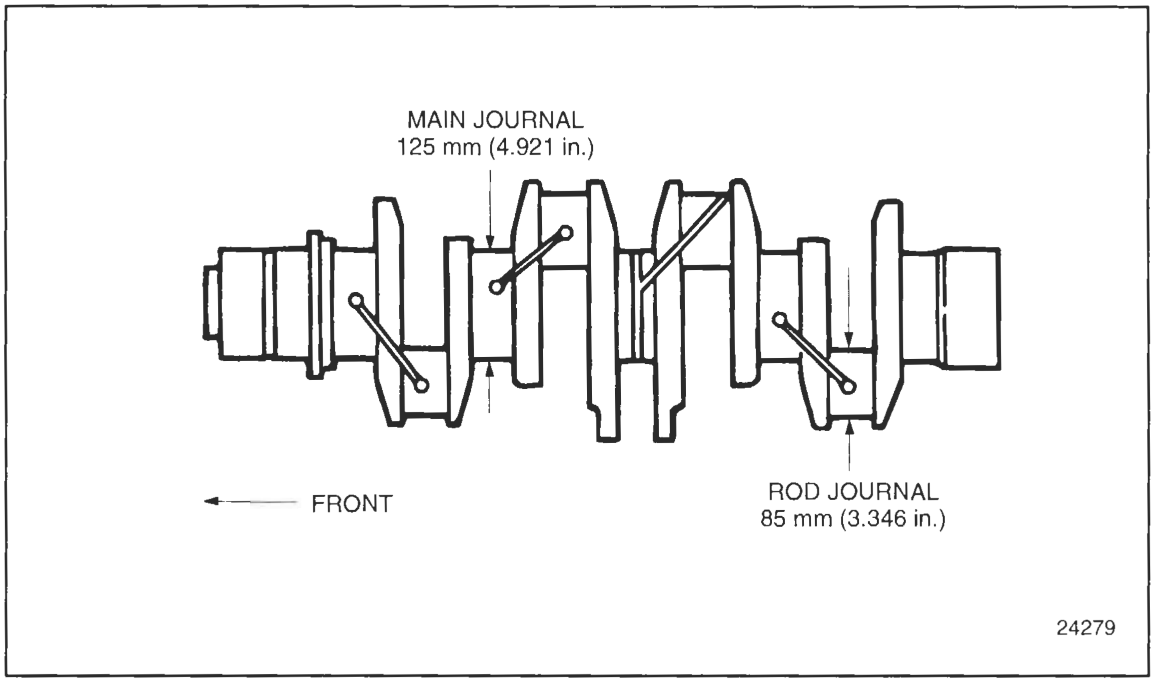


Figure 1-95 Crankshaft Lubricating Oil Holes

Twelve tapped holes, equally spaced, are provided on the rear butt for attaching the flywheel. There are six or twelve equally spaced tapped holes on the front butt of the crankshaft for attaching the crankshaft pulley and vibration damper. No locating dowels are provided at either end.

Each standard main bearing journal is 125.000-124.975 mm (4.921-4.920 in.) in diameter and each standard connecting rod journal is 85.000-84.975 mm (3.346-3.345 in.) in diameter.

New crankshafts with smaller radii fillets replaced the former crankshafts, effective with the following engine serial numbers 4R6665 built October 26, 1994. This change was made to permit installation of new, wider connecting rod bearings that increase rod bearing oil film thickness and reduce bearing pressures. The fillets on the new crankshafts have a radius of 4.0-3.5 mm (.157-.138 in.). The fillets on the former crankshafts had a radius of 6.0-5.5 mm (.236-.216 in.). To conform with this change, new connecting rods with smaller rod chamfers were also released. Refer to section 1.19 for information on the new connecting rods and bearings.

The new crankshafts, bearings, and connecting rods must be used together to ensure interchangeability. Former parts cannot be mixed with new parts in the same engine. The former crankshafts will no longer be available.

1.7.1 Repair or Replacement of Crankshaft

To determine if repair is possible or replacement is necessary perform the following procedure. See Figure 1–96.

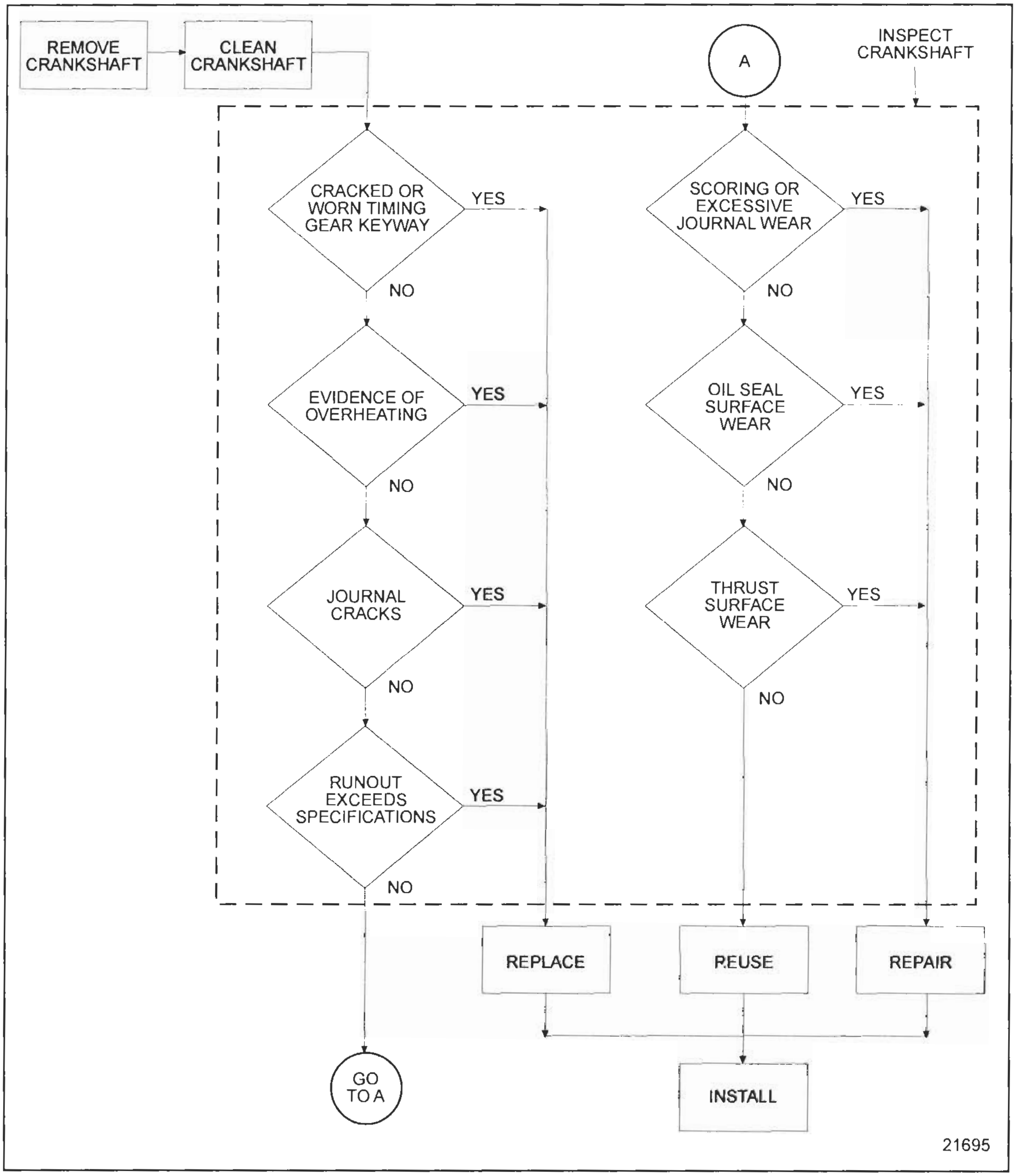


Figure 1–96 Flowchart for Repair or Replacement of Crankshaft

1.7.2 Cleaning and Removal of Crankshaft

When removal of the crankshaft becomes necessary, first remove the transmission, then proceed as follows:

1. Steam clean the exterior of the engine.
2. Drain the cooling system. Refer to section 13.5.4.
3. Drain the lubricating oil. Refer to section 13.5.1.
4. Attach suitable chain hoist and spreader bar with hooks to the three lifter brackets (one at the front and two at the rear). Remove all engine-to-base attaching bolts and remove the engine from its base. Refer to section 1.1.2. See Figure 1-4.

CAUTION:
Be absolutely sure the engine is securely attached to the stand before releasing the lifting sling. Severe injury to personnel and destruction of engine parts will result if the engine breaks away from the stand.

5. Remove and inspect all of the accessories and assemblies with their attaching parts as necessary to permit the engine block adapter, to be bolted to the intake (left) side of the cylinder block. Mount the engine to the overhaul stand, J 29109 with adapter, J 39652 attached. Refer to section 1.1.2. See Figure 1-6.
6. Remove and inspect the oil pan. Refer to section 3.9.2.
7. Remove and inspect the balance shaft assembly containing the balance shaft, gear, and oil pump. Refer to section 1.27.2.
8. Remove and inspect the flywheel. Refer to section 1.14.2.
9. Remove and inspect flywheel housing. Refer to section 1.16.2.

NOTICE:
Use care when removing the crankshaft pulley as the vibration damper may come off. If the damper is allowed to fall, damage to the internal components of the damper may result.

10. Loosen and remove two of the crankshaft pulley retaining bolts and hardened washers 180° apart and install two flywheel guide studs, J 36235, in their place. Then loosen and remove the remaining four pulley retaining bolts and hardened washers. Refer to section 1.12.2.
11. Remove and inspect the viscous vibration damper. Refer to section 1.12.2 for removal and refer to section 1.12.2.1 for inspection.

12. Remove and inspect the engine front support and gear case cover. Refer to section 1.10.2 for removal and refer to section 1.10.2.1 for inspection.
13. Remove and inspect the cylinder head. Refer to section 1.2.2 for removal and refer to section 1.2.3 for inspection.
14. Remove and inspect the piston and connecting rod assemblies. Refer to section 1.18.2 and refer to section 1.18.3.1 for inspection.

NOTE:
The connecting rod caps must be reinstalled to their respective connecting rods. The main bearing caps should be kept in sequence, so that they may be installed to their original positions.

15. Loosen and remove the main bearing cap bolts. Remove the main bearing caps.
16. Remove and inspect the thrust washers from each side of the No. 4 main bearing cap.
17. Remove and inspect the crankshaft, including the crankshaft gear and timing wheel. Refer to section 1.26.2.
18. Remove and inspect the timing gear and timing wheel.
19. Remove the Woodruff key from the slot in the front crankshaft hub.

1.7.2.1 Inspection of Crankshaft

Perform the following steps for crankshaft inspection:

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

1. Clean out the oil passages thoroughly with a stiff wire brush. Clean the crankshaft with fuel oil and dry it with compressed air.
2. Inspect the crankshaft timing gear keyway for evidence of cracks or wear. Replace the crankshaft if these conditions are evident.
3. If the crankshaft shows evidence of excessive overheating, replace the crankshaft since the heat treatment has probably been destroyed.
4. Check the crankshaft journal surfaces for score marks and other imperfections. If excessively scored, the journal surfaces must be reground. Refer to section 1.A.
5. Carefully, inspect the front and rear end of the crankshaft in the area of the oil seal contact surface for evidence of a rough or grooved condition. Any imperfections of the oil seal contact surfaces will result in oil leakage at these points.
6. If the crankshaft oil seal contact surfaces are grooved, the seal surfaces must be sleeved and an oversized seal used. Refer to section 1.8.
7. Check the crankshaft thrust surfaces for excessive wear or grooving. If excessively worn, the thrust surfaces must be reground. Refer to section 1.A.
8. Check the crankshaft timing gear for worn or chipped teeth. Inspect the timing wheel for bent or otherwise damaged teeth. Replace as necessary. Refer to section 1.26.2.1.
9. Check the crankcase journal runout. Refer to section 1.7.2.2.
10. Check the journal alignment. Refer to section 1.7.2.3.
11. Check the journal measurements. Refer to section 1.7.2.4.
12. Inspect the crankshaft for cracks. Refer to section 1.7.2.5.

1.7.2.2 Crankshaft Journal Runout Measurements

Support the crankshaft on its front and rear journals on Vee-blocks or the inverted engine block with only the front and rear upper bearing shells in place. Check the intermediate main journals with a dial indicator for runout when the crankshaft is rotated.

When checking the crankshaft bow, if the runout is greater than that listed in Table 1-2, the crankshaft must be replaced.

Journals Supported On	Journals Measured	Maximum Runout (Total Indicator Reading)
No. 1 and No. 5	No. 2 and No. 4	0.075 mm (.003 in.)
No. 1 and No. 5	No. 3	0.130 mm (.005 in.)

Table 1–2 Crankshaft Bow

1.7.2.3 Adjacent Journal Alignment

When runout on the adjacent journals is in opposite directions, the sum must not exceed 0.076 mm (.003 in.) total indicator reading. When the high spots of runout on the adjacent journals are in the same direction, the difference must not exceed 0.076 mm (.003 in.) total indicator reading.

1.7.2.4 Journal Diameter Measurements

Measure all of the main and connecting rod bearing journals diameters. See Figure 1-97.

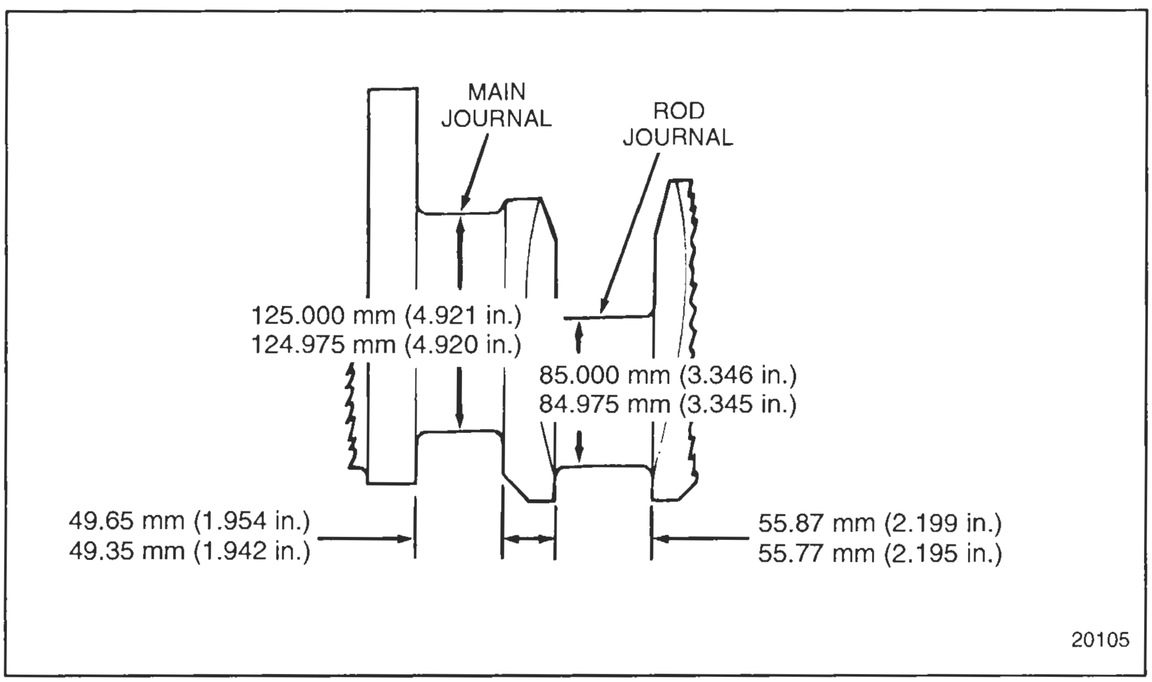


Figure 1–97 Dimensions of Crankshaft Journals

Measure the journals at several places on the circumference so that taper, out-of-round and bearing clearances can be determined. If the crankshaft is worn so that the maximum connecting rod or main bearing journal-to-bearing shell clearance (with new shells) exceeds 0.1270 mm (.005 in.) (connecting rod journals) or 0.1412 mm (.0056 in.) (main bearing journals), the crankshaft must be reground. Measurements of the crankshaft should be accurate to the nearest 0.0025 mm (.0001 in.). Also, if the main bearing journal taper of a used crankshaft exceeds 0.0381 mm (.0015 in.) or the out-of-round is greater than 0.0254 mm (.001 in.), the crankshaft must be reground. Refer to section 1.A.

Also, measure the distance between crankshaft thrust washer surfaces. See Figure 1-98.

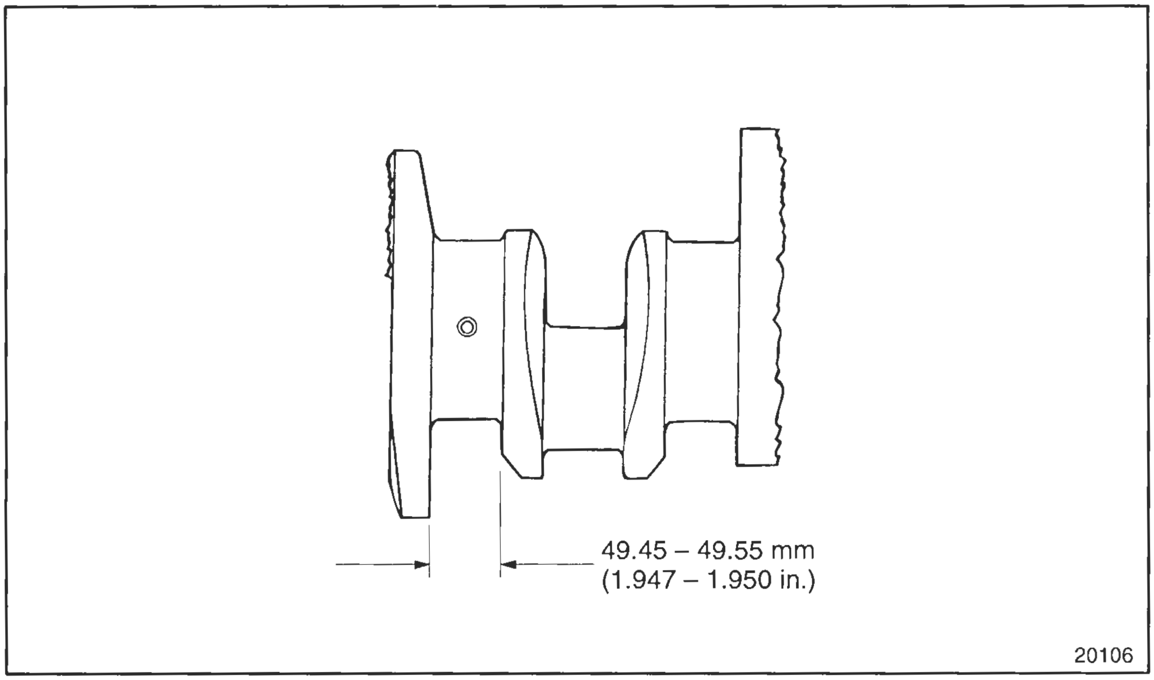


Figure 1–98 Standard Dimensions at No. 4 Main Bearing Thrust Washers

1.7.2.5 Inspection for Cracks

Carefully check the crankshaft for cracks which start at an oil hole and follow the journal surface at an angle of 45° to the axis. Any crankshaft with such cracks must be replaced. Several methods of determining the presence of minute cracks not visible to the eye are available: refer to section 1.7.2.6 for magnetic particle method, refer to section 1.7.2.7 for fluorescent magnetic particle method, or refer to section 1.7.2.8 for florescent penetrant method.

1.7.2.6 Magnetic Particle Method

Magnetize the crankshaft and then covered it with a fine magnetic powder or solution. Flaws, such as cracks, form a small local magnet which causes the magnetic particles in the powder or solution to gather there, effectively marking the crack.

NOTICE:
Very fine cracks may be missed using the magnetic particle method especially on discolored or dark surfaces.

NOTICE:
The crankshaft must be demagnetized after the test to avoid engine damage.

If the crankshaft is discolored or has dark surfaces, the magnetic particle method should not be used. Refer to section 1.7.2.7 for suitable alternate method.

1.7.2.7 Fluorescent Magnetic Particle Method

This method is similar to the magnetic particle method, refer to section 1.7.2.6, but is more sensitive since it employs magnetic particles which are fluorescent and glow under black light. Very fine cracks that may be missed under the first method, especially on discolored or dark surfaces, will be disclosed under the black light.

NOTICE:
The crankshaft must be demagnetized after the test to avoid engine damage.

1.7.2.8 Fluorescent Penetrant Method

This is a method which may be used on both non–magnetic and magnetic materials. A highly fluorescent liquid penetrate is applied to the part. Then the excess penetrant is removed from the surface and the part is dried. A developing powder is then applied which helps to draw the penetrant out of the flaws by capillary action. Inspection is carried out under a black light.

A majority of indications revealed by the above inspection methods are normal and harmless and only in a small percentage of cases is reliability of the part impaired when indications are found. Since inspection reveals the harmless indications with the same intensity as the harmful ones, detection of the indications is but a first step in the procedure. **Interpretation** of the indications is the most important step.

After manufacture, all crankshafts are magnetic-particle-inspected to eliminate the possibility of defective shafts being placed into original equipment.

Crankshaft failures are rare and when one cracks or breaks completely, it is very important to make a thorough inspection for contributory factors. Unless abnormal conditions are discovered and corrected, there will be a repetition of the failure.

There are two types of loads imposed on a crankshaft in service: a bending force and a twisting force. The design of the shaft is such that these forces produce practically no stress over most of the surface. Certain small areas, designated as critical areas, sustain most of the load. See Figure 1-99.

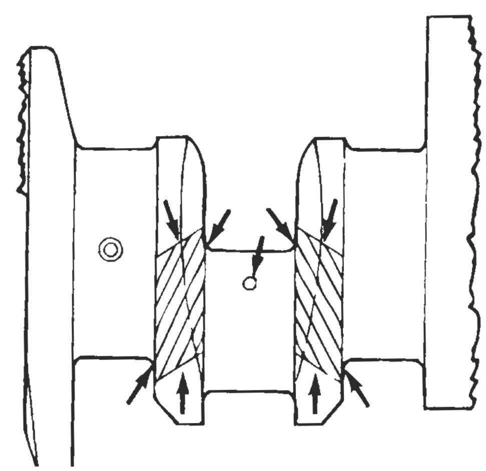


Figure 1–99 Critical Crankshaft Loading Zones

1.7.2.9 Bending Fatigue

Failures can result from bending of the crankshaft.

The crankshaft is supported between each of the cylinders by a main bearing and the load imposed by the gas pressure on top of the piston is divided between the adjacent bearings. An abnormal bending stress in the crankshaft, particularly in the crank fillet, may be a result of misalignment of the main bearing bores, improperly fitted bearings, bearing failures, loose or broken bearing caps, or unbalanced pulleys. Also, drive belts which are too tight will impose a bending load upon the crankshaft.

Failures resulting from bending start at the pin fillet and progress throughout the crank cheek, sometimes extending into the main journal fillet. If main bearings are replaced due to one or more badly damaged bearings, a careful inspection must be made to determine if any cracks have started in the crankshaft. These cracks are most likely to occur on either side of the damaged bearing.

1.7.2.10 Torsional Fatigue

Failures result from torsional vibration which takes place at high frequency. A combination of abnormal speed and load conditions may cause the twisting forces to set up a vibration, referred to as torsional vibration, which imposes high stresses at the locations. See Figure 1–100.

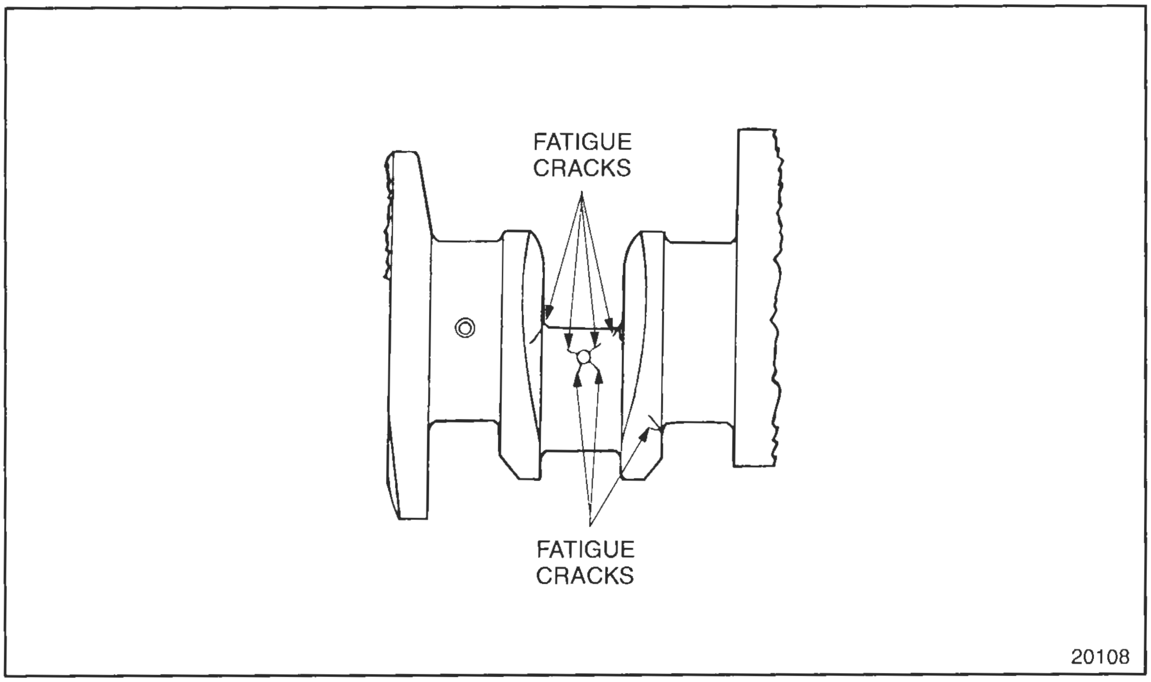


Figure 1–100 Crankshaft Fatigue Cracks

Torsional stresses may produce a fracture in either the connecting rod journal or the crank cheek in the rear. Torsional failures may also occur at the front end of the crankshaft at the crankshaft timing gear drive key slot. Connecting rod journal failures are usually at the fillet or oil hole at 45° to the axis of the shaft.

A loose, damaged or defective vibration damper, a loose flywheel or the introduction of improper or additional pulleys or couplings are usual causes of this type of failure. Also, overspeeding of the engine or overriding the engine electronic control system to allow engine overspeeding may be contributory factors.

1.7.2.11 Crankshaft Cracks

As previously mentioned, most of the indications found during inspection of the crankshaft are harmless. The two types of indications to look for are circumferential fillet cracks at the critical areas and 45° cracks (45° to the axis of the shaft) starting from either the critical fillet locations or the connecting rod journal holes.
See Figure 1–100. Replace the crankshaft when cracks of this nature are found. Refer to section 1.7.3.

1.7.2.12 Crankshaft Grinding

The use of properly remanufactured crankshafts is very important to maximize crankshaft main and connecting rod bearing life.

Remanufactured crankshafts must conform to specifications shown in the previous illustration. See Figure 1-100. The dimensional requirements for journal axial profile, radial chatter and oil hole washout require confirmation with a Gould 1200 Surface Analyzer (or equivalent). Information on Gould 1200 is available in the "Glossary". Refer to section 1.A.

NOTE:
Visual inspection cannot be relied upon to confirm the compliance to journal quality specifications.

The procedure of crankshaft journal polishing can easily create axial profile and oil hole washout conditions beyond specifications. Any polishing operation should be followed by Gould 1200 (or equivalent) measurements to assure conformance to remanufactured specifications. Refer to section 1.A.

All used crankshafts that have not been reground must meet the dimensional specifications standard or be reground to specifications. Refer to section 1.A.

In addition to standard size crankshaft thrust washers, 0.127 mm (.005 in.) and 0.254 mm (.010 in.) oversize thrust washers are available. Refer to section 1.A for thrust surface specifications are listed in Table 1-14.

Remanufactured crankshafts should be stamped on the edge of the No. 1 crank throw (counterweight) with the appropriate undersize dimensions for identification purposes.

NOTE:
Crankshaft main bearing journals and/or connecting rod journals which exhibit discoloration due to excessive overheating from bearing failure are NOT acceptable for rework.

If one or more main or connecting rod journals require grinding, grind all of the main journals or all of the connecting rod journals to the same required size.

1.7.3 Installation of Crankshaft

Install the crankshaft using the following procedure:

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

1. Steam clean it to remove the rust preventative and blow out the oil passages with compressed air.
2. Refer to section 1.9 for main bearing details and install the upper main bearing shells in the block. If the old bearing shells are to be used again, install them in the same locations from which they were removed.

NOTE:
When a new or reground crankshaft is installed, ALL new main and connecting rod (upper and lower) bearing shells and new thrust washers must also be installed.

NOTE:
If the crankshaft surfaces were reground, it may be necessary to install oversize thrust washers on one or both sides of the No. 4 main journal. See Figure 1–94.

3. Install the thrust washer upper halves in the counterbores on either side of the No. 4 bearing saddle. Coat the backs of the thrust washers (without oil grooves) with petroleum jelly and stick them in place with the oil-grooved sides facing away from the saddle.

NOTE:
It may be easier to remove the bull gear assembly and re–time the engine; refer to section 1.21.

4. Apply clean engine oil 360° around all crankshaft bearing journals and install the crankshaft in place so that the timing marks on the crankshaft timing gear and the bull gear are aligned. Refer to section 1.21.
5. Install the main bearing shells in the main bearing caps as follows:
   [a] Align the tang on the lower main bearing shell with the groove in the main bearing cap. Install the bearing shell to the main bearing cap.

NOTE:
The main bearing caps are bored in position and stamped with a position number. They must be installed in their original positions, with the marked (numbered) side of each cap toward the cooler (right) side of the cylinder block.

[b] If the old bearing shells are to be used again, install them in the same bearing caps from which they were removed.

6. Install the main bearing caps together with lower bearing shells in place. Install the main bearing cap bolt. See Figure 1-101.

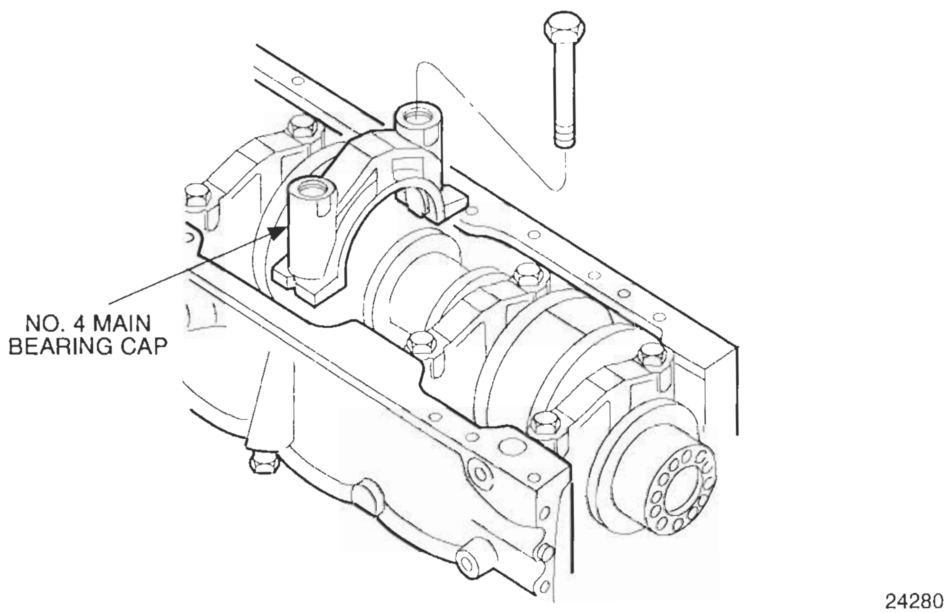


Figure 1–101 No. 4 Main Bearing Cap Installation

7. Apply a small quantity of International Compound No. 2 (or equivalent) to the bolt threads and underside of the bolt heads. Install the main bearing cap bolts and draw them up snug. Rap the main bearing caps sharply with a fiber mallet or plastic hammer to insure the caps are fully seated.

NOTE:
If the bearings have been installed properly, the crankshaft will turn freely with all of the main bearing cap bolts drawn to the specified torque.

8. Tighten all of the main bearing cap bolts to 470–530 N·m (347–391 lb·ft) torque. Begin at the center caps and work progressively toward each end. Tighten the bolts to half the specified torque and then repeat the tightening sequence to the torque limit.

9. Install a dial indicator to the cylinder block. See Figure 1–102.
10. Check the crankshaft end by moving the crankshaft toward the gage with a small (less than 12 in., 0.3 m) pry bar. See Figure 1–102. Keep a constant pressure on the pry bar and zero the pointer on the dial indicator. Then, remove and insert the pry bar on the other side of the bearing cap. Force the crankshaft in the opposite direction and note the amount of end play on the dial. The end play should be 0.097–0.419 mm (.004–.017 in.). Insufficient end play can be the result of a misaligned No. 4 main bearing, a mislocated upper thrust washer or a burr or dirt on the inner face of one or more of the thrust washers.

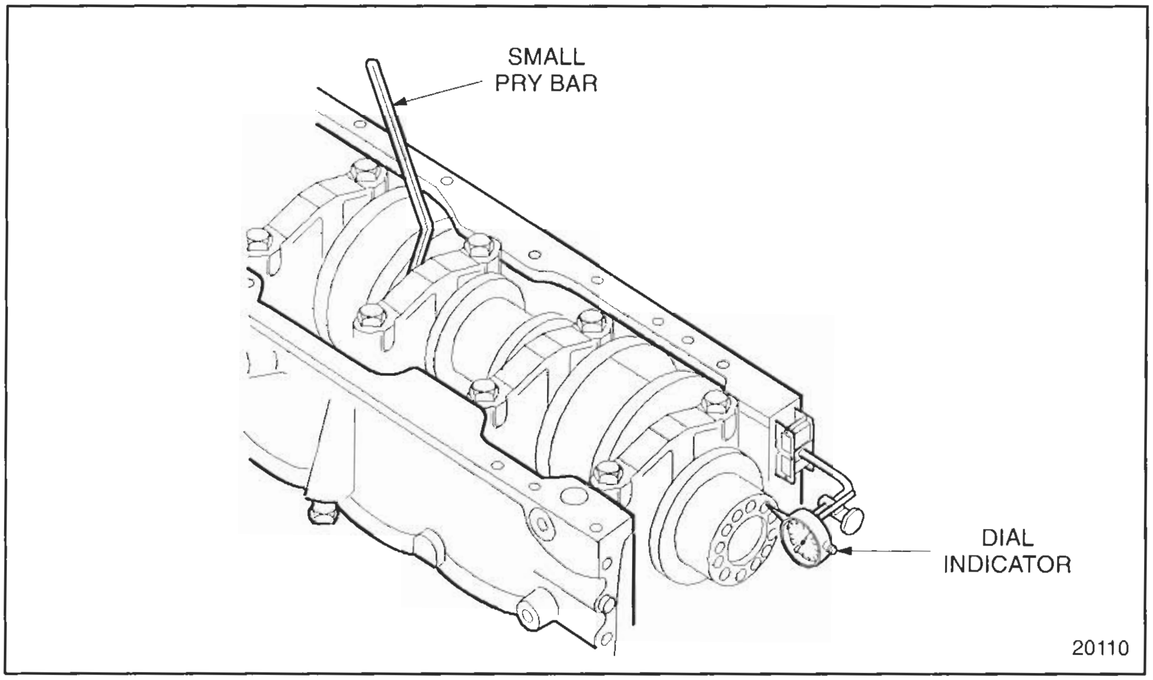


Figure 1–102 Measuring Crankshaft End Play

11. Assemble the timing wheel and crankshaft gear on the crankshaft. Refer to section 1.26.3.
12. Install the piston and connecting rod assemblies. Refer to section 1.18.5. Tighten the connecting rod cap nuts to 160–185 N·m (118–137 lb·ft) torque.
13. Install the cylinder head. Refer to section 1.2.5.
14. Install the flywheel housing. Refer to section 1.16.3.
15. Replace the rear crankshaft seal with new seal and sleeve assembly. Refer to section 1.8.5.
16. Install the flywheel. Refer to section 1.14.3.

17. Install the lubricating oil pump, inlet and outlet pipes. Refer to section 3.2.5.
18. Install the gear case cover and engine front support. Refer to section 1.10.3.
19. Replace the front crankshaft seal with new seal and sleeve assembly. Refer to section 1.8.5.
20. Install the viscous vibration damper. Refer to section 1.12.3.
21. Install the crankshaft pulley. Refer to section 1.13.3.
22. Install the oil pan. Refer to section 3.9.3.
23. Use a chain hoist and spreader bar with hooks attached to the lifting brackets at each end of the engine and remove the engine from the overhaul stand.
24. Remove the overhaul stand adapter plate from the engine block.
25. Install any accessories that were removed.
26. Install the engine to the equipment from which it was removed.
27. Fill the cooling system. Refer to section 13.5.4.
28. Fill the engine crankcase to correct operating level. Refer to section 13.5.1.
29. After replacing the main or connecting rod bearings or installing a new or reground crankshaft, operate the engine as outlined in the "Run–In Schedule." Refer to section 11.6.2.

1.8 CRANKSHAFT OIL SEALS

An oil seal is used at each end of the crankshaft to retain the lubricating oil in the crankcase. The sealing lips of the crankshaft oil seals are held firmly, but not tight, against the crankshaft sealing surfaces by a spring, thus preventing oil from escaping from the engine crankcase.

A unidirectional single-lip crankshaft oil seal, with a dust lip, is used at the front and rear of the crankshaft. The rear oil seal is pressed into the flywheel housing. See Figure 1-103.

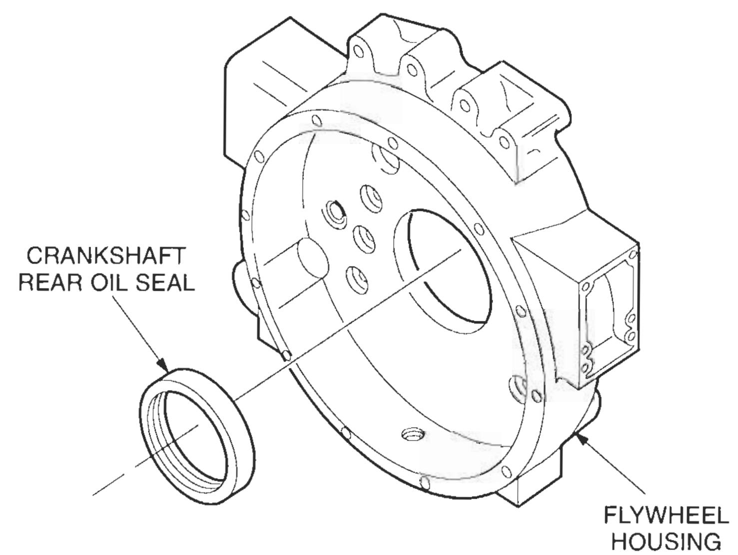


Figure 1-103 Crankshaft Rear Oil Seal Mounting in Flywheel Housing

NOTICE:
Failure to use the required seal in a dry or wet flywheel housing environment may result in seal damage and oil leakage.

A unidirectional, laydown type, single Teflon lip seal with an integral dust lip is used at the rear of engines with dry flywheel housings.

A unidirectional, laydown type, single Teflon lip seal with an integral dust lip is used at the rear of engines with wet flywheel housings.

The unitized front oil seal is pressed into the gear case cover after the cover is installed. See Figure 1–104.

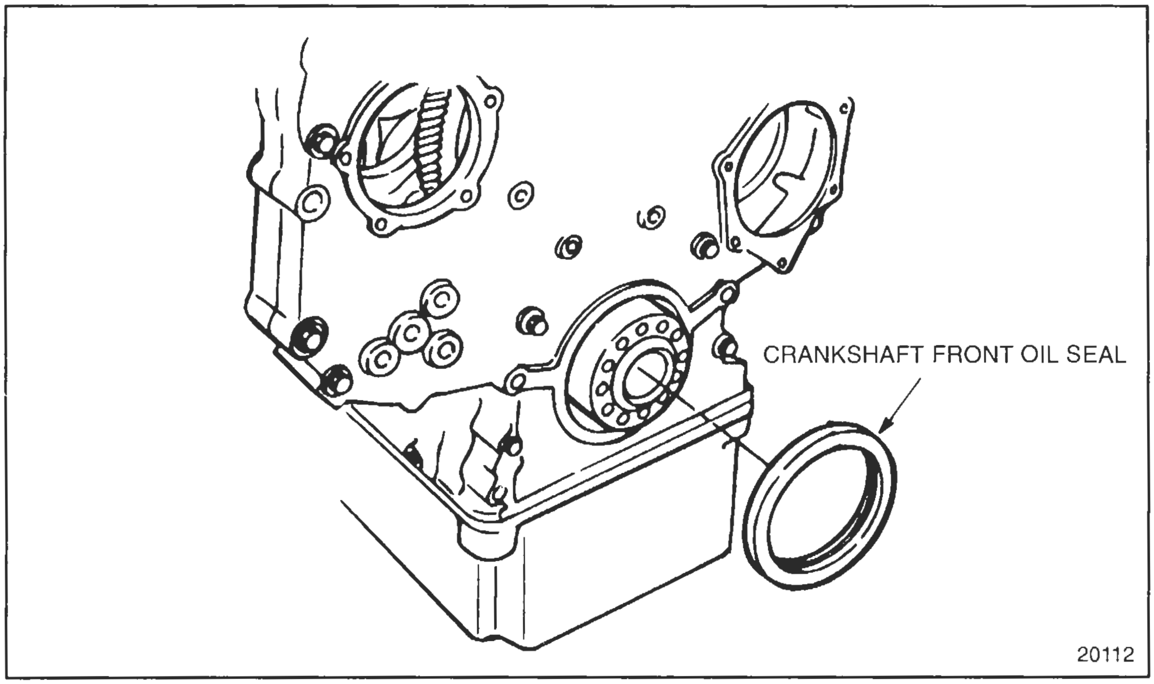


Figure 1–104 Crankshaft Front Oil Seal Mounting

The lip of the seals bears against the crankshaft hub surface.

1.8.1 Repair or Replacement of Oil Seal

To determine if repair is possible or replacement is necessary perform the following procedure. See Figure 1–105.

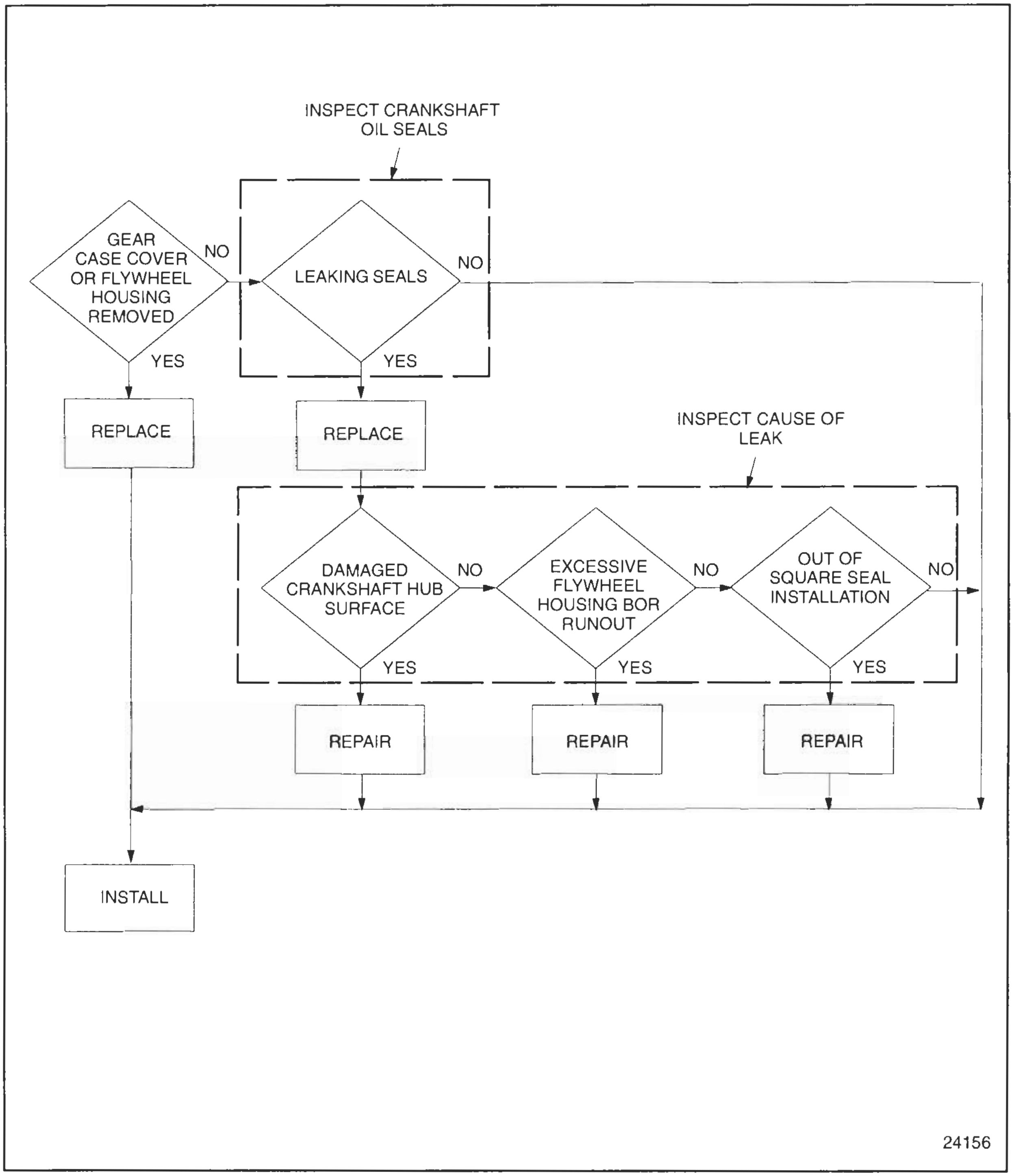


Figure 1–105 Flowchart for Repair or Replacement of Crankshaft Oil Seal

1.8.2 Crankshaft Oil Seal Removal

Remove the crankshaft oil seal as follows:

NOTICE:
Due to the possibility of damage to the crankshaft oil seals, any time the gear case cover or flywheel housing is removed from the engine, the crankshaft oil seals must be replaced.

If the gear case cover or flywheel housing is removed. Refer to section 1.8.3. If the gear case cover of flywheel housing is installed. Refer to section 1.8.4.

1.8.3 Gear Case Cover or Flywheel Housing Removed

If the gear case cover (refer to section 1.10) or flywheel housing (refer to section 1.16) is removed from the engine, then the crankshaft oil seals may be removed, as follows:

1. Support the outer face of the gear case cover or flywheel housing on wood blocks.
2. Drive the oil seal out with a brass drift and hammer. Clean the seal bore in the cover or housing. See Figure 1-106.

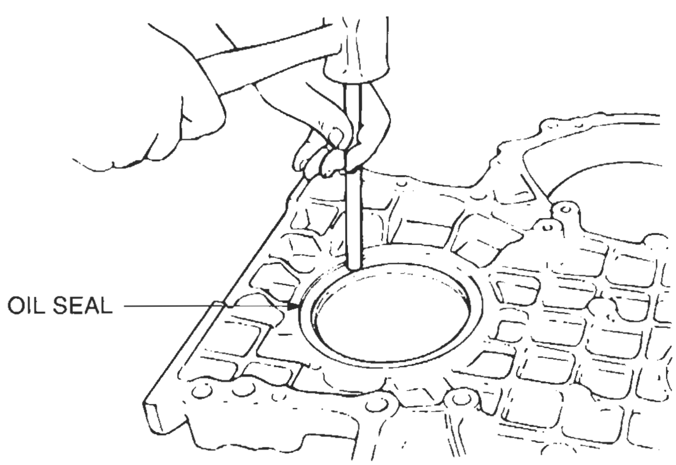


Figure 1–106 Front Crankshaft Oil Seal Removal

1.8.4 Gear Case Cover or Flywheel Housing Installed

When necessary, the crankshaft oil seals may be taken out without removing the gear case cover or flywheel housing. This may be done by using oil seal removal tool, J 35993.

1. To replace the front oil seal, first remove the crankshaft pulley. Refer to section 1.13.2. Second remove the vibration damper. Refer to section 1.12.2.
2. To replace the rear oil seal, with the transmission removed, remove the flywheel. Refer to section 1.14.2.
3. Install the oil seal removal tool J 35993 over the butt end of the crankshaft (front or rear).

NOTE:
Six small holes are provided near the inside diameter of the tool for installing self–tapping screws through the tool and into the oil seal. Most seals can be removed using only three of the holes, forming a triangle pattern. However, use of all six holes provides maximum grip of the seal and reduces the possibility of pull–out of the tool from the seal.

4. Use a variable speed drill and the J 35993–5 nut driver supplied to install one of the self–tapping screws through the remover tool near the twelve o'clock position, and into the oil seal. See Figure 1–107.

NOTE:
Use care when the screws are almost completely installed, to slow down the drill and prevent stripping the screws.

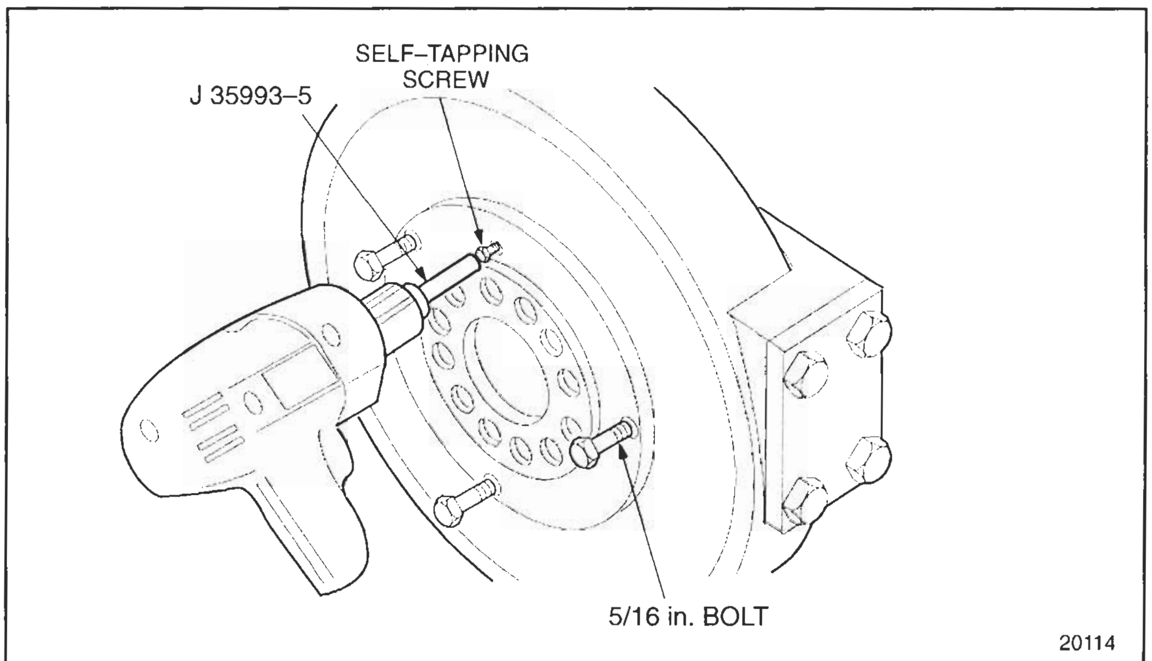


Figure 1–107 Self–tapping Screw Installation

5. Continue to install self-tapping screws into the oil seal. Use a minimum of three screws.
6. With the self-tapping screws tight against the remover tool, turn the 5/16 in. bolts on the outer edge of the remover, one turn each, working in a clockwise pattern.
7. Continue turning the 5/16 in. bolts, one turn each, until the oil seal is removed.

NOTE:
If seal removed is an oversized seal with wear sleeve, the old seal must be removed.

8. Remove the self-tapping screws from the tool. Discard the oil seal.

To remove a worn sleeve use crank oil wear sleeve remover, J 37075-A. See Figure 1-108.

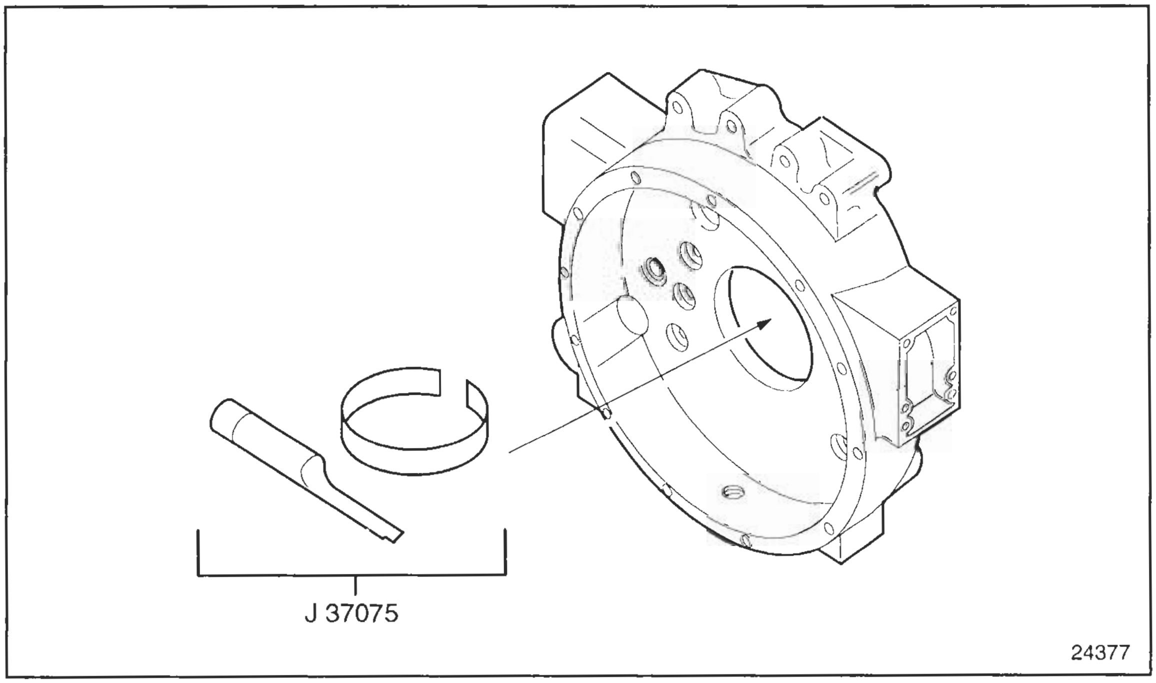


Figure 1-108 Oil Sleeve Wear Sleeve Removal

1. Install hardened steel sleeve into flywheel housing bore. Using socket and breaker bar, rotate tool in three different locations, 2, 4, and 8 o' clock positions until the sleeve stretches sufficiently so it can be slipped off the end of the crankshaft.
2. Crocus cloth may be used to clean up the high spots from the surface of the crankshaft. Clean the crankshaft contact surface thoroughly.

1.8.5 Installation of Crankshaft Oil Seal/Wear Sleeve

Install the front oil seal as follows:

NOTICE:
To avoid seal lip damage, do not separate components of the new assembly before installation or attempt to install them using the former installation procedures or tools. If the seal is separated from the sleeve, both parts **must** be scrapped. Do not attempt to reassemble.

An oil seal sleeve pressed onto the end of the crankshaft provides a replacement wear surface at the point of contact with the oil seal. An oversize I.D. oil seal is used with the sleeve. The sleeve and oversize seal are supplied assembled. The assembly is installed using the crankshaft oil seal/sleeve installation tool, J 35686–A. See Figure 1–109 and see Figure 1–110.

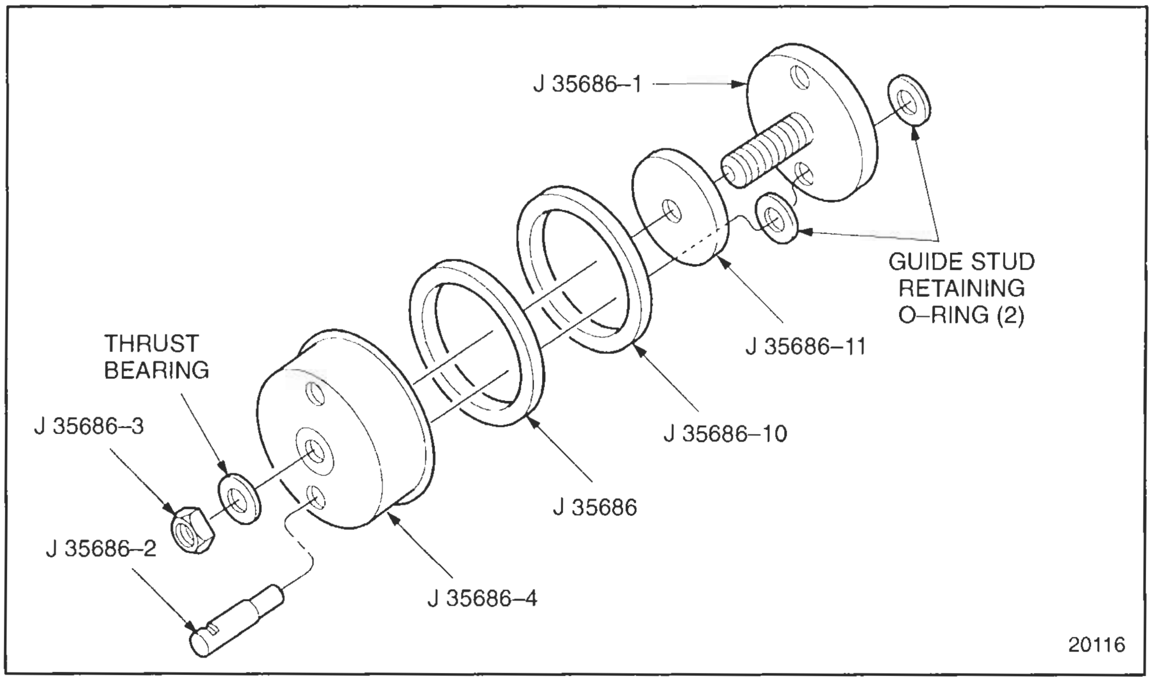
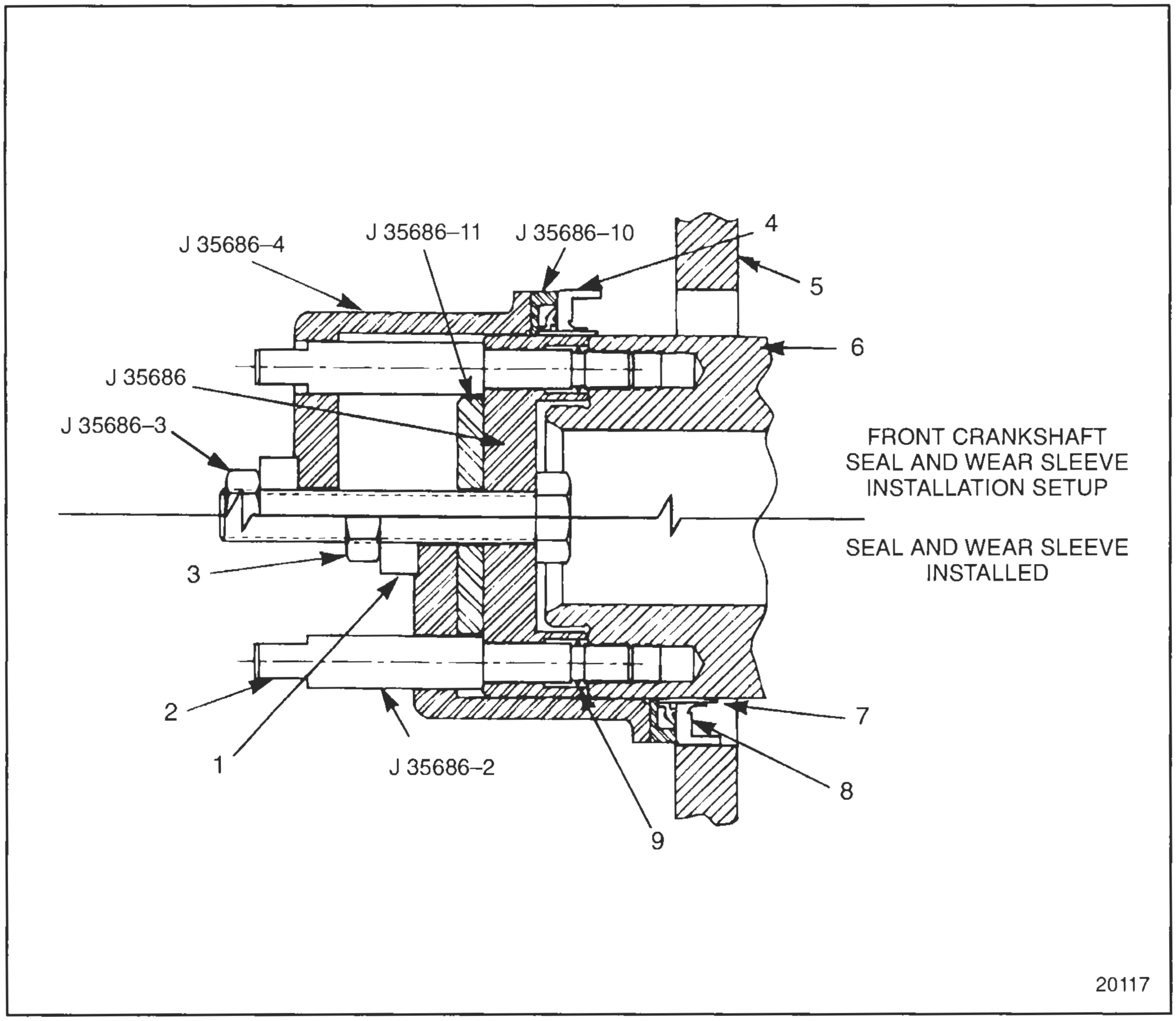


Figure 1–109 Front Crankshaft Oil Seal/Sleeve Installation Tool Set



1. Thrust Plate
2. Wrench Flat 1/2 in.
3. 3/4–10 Hex Nut
4. Seal and Wear Sleeve Assembly DDC Part No. 23513485
5. Gear Case
6. Shaft
7. Wear Sleeve
8. Oil Seal
9. Guide Stud Retainer (O–Ring)

Figure 1–110 Crankshaft Oil Seal Installer Stack–up (Front)

Install an oversize oil seal/sleeve, as follows:

NOTE:
The assembly used in dry flywheel housings has a unidirectional, laydown type Teflon inner sealing lip and a forward facing Teflon dust lip. The assembly used in wet flywheel housings has a double–lip seal with unidirectional inner and outer laydown type Teflon sealing lips.

1. Install the new, oversize oil seal and wear sleeve assembly to the housing, J 35686-4. See Figure 1-111.

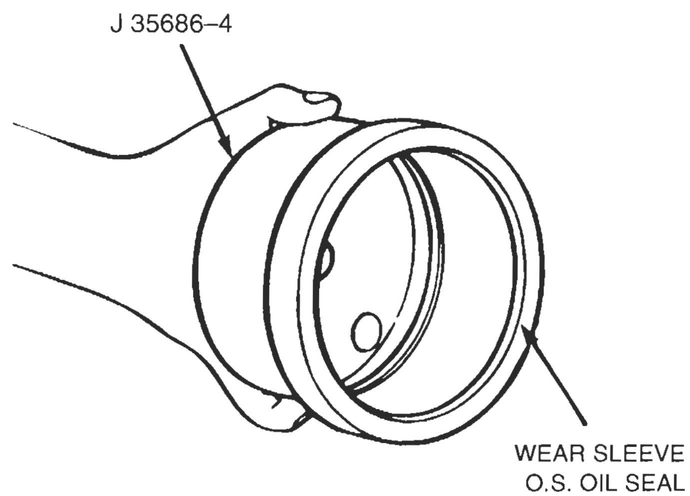


Figure 1–111 Oil Seal/Wear Installation Tool Setup

2. Add new J 35686-10 adapter ring and J 35686-11 spacer along with J 35686-6 spacer. Do not separate the two.

To install the rear oil sleeve:

1. Install the two guide studs, J 35686-2, through the holes provided in the base, J 35686-1 and into two of the tapped holes in the crankshaft, 180° apart. See Figure 1-112. Tighten the guide studs using the appropriate wrench on the flats of the studs. The base must be tight against the end of the crankshaft.

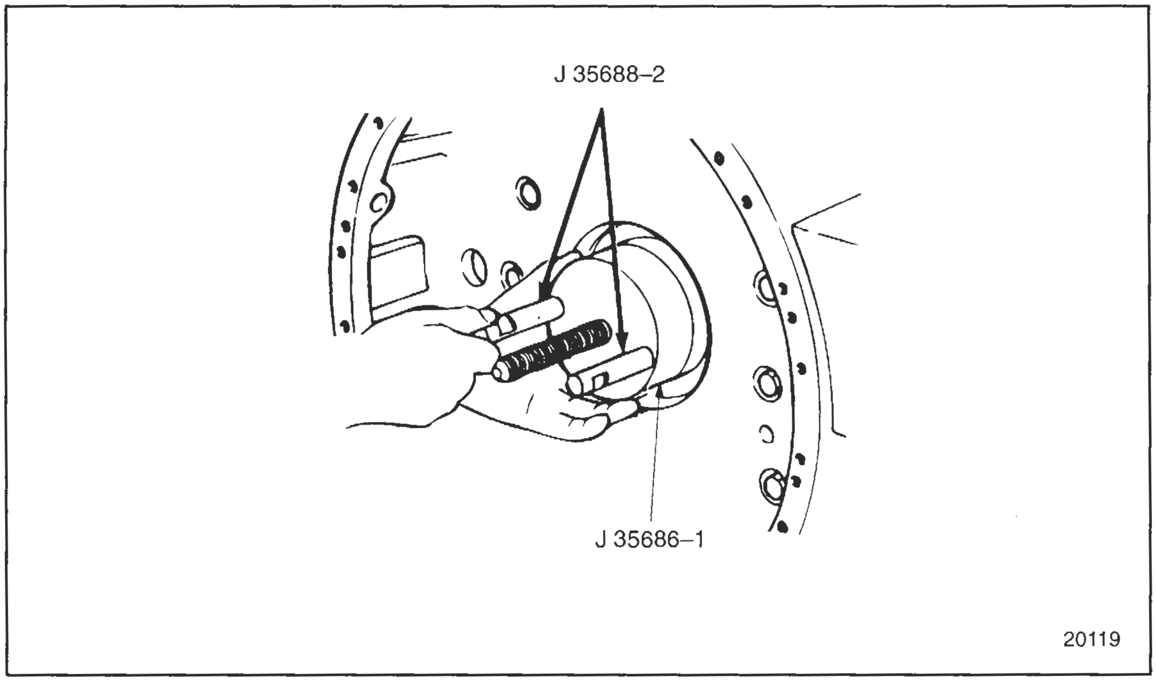


Figure 1–112 Rear Oil Seal Installation Tool Setup

2. For rear crankshaft oil seal installations only, install spacer J 35686–6 and J 35686–11, to the center screw of the base. See Figure 1–113 and see Figure 1–110.

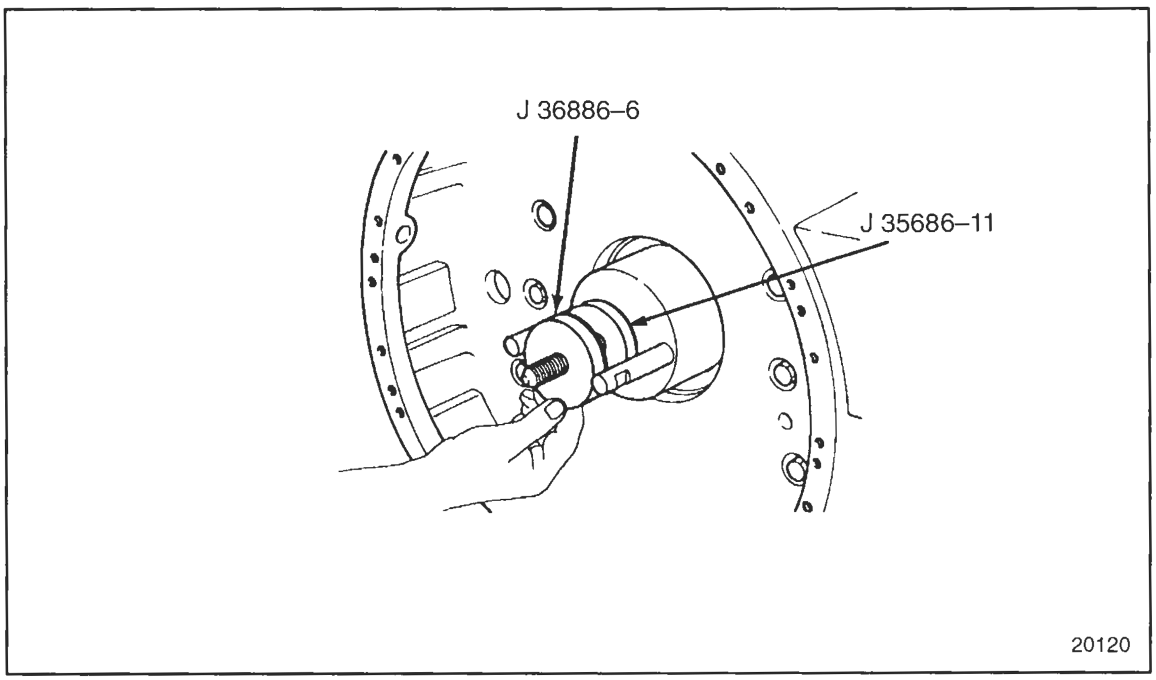


Figure 1–113 Rear Oil Seal Installation Spacer Setup

3. Install the housing (pusher), J 35686–4, and adapter ring, J 35686–10, with seal and sleeve assembly in place on the guide studs. See Figure 1–114.

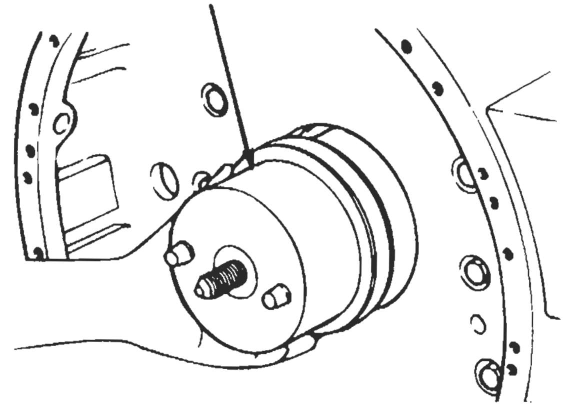


Figure 1–114 Rear Oil Seal/Sleeve Installation

4. Install the thrust bearing tool with the case side toward the installer housing. Install the hex nut to the center screw of the base. See Figure 1–115.

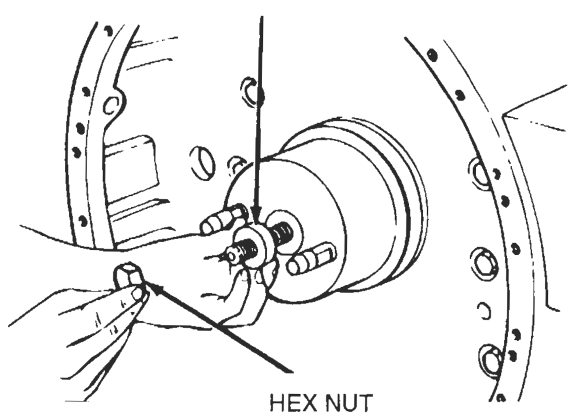


Figure 1–115 Tool Installation

5. Tighten the hex nut by hand until all the slack is taken up. Use a ratchet and socket to tighten the hex nut, and install the wear sleeve to the crankshaft and the oil seal to the flywheel housing/gear case cover. See Figure 1-116.

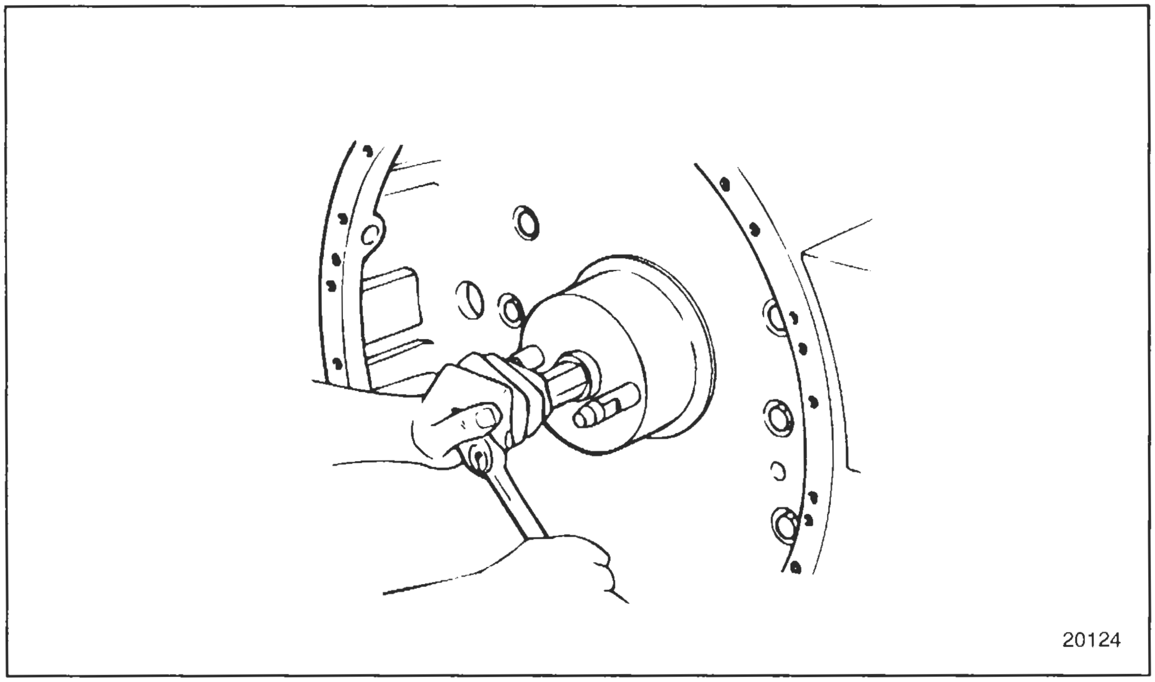


Figure 1–116 Oil Seal/Sleeve Installation

6. When the inside surface of the housing is seated against the base (spacers on rear oil seal installation), the seal and sleeve are properly positioned and installed.

1.8.5.1 Inspection of Crankshaft Oil Seal

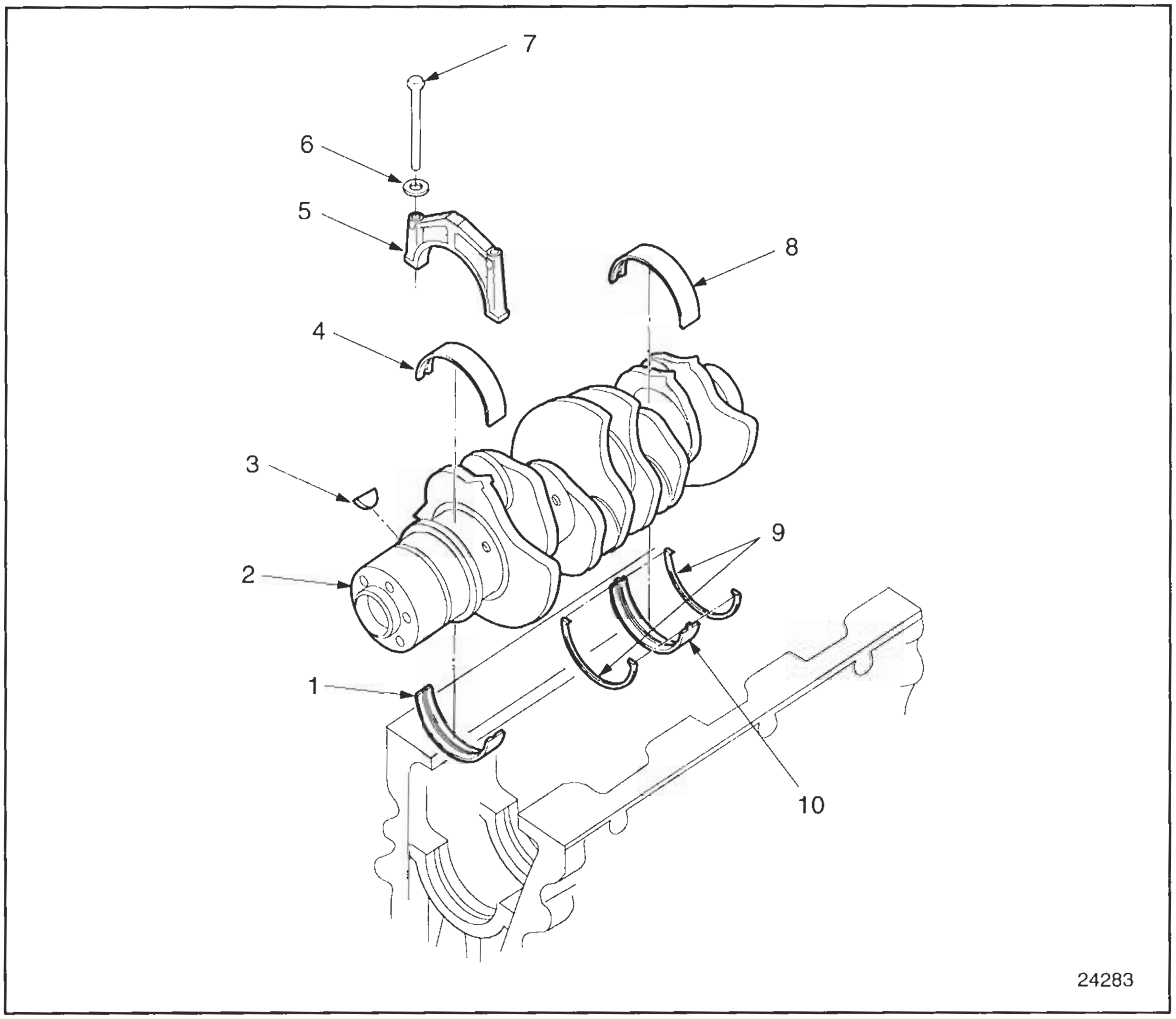
Crankshaft oil seal leaks may indicate worn or damaged oil seals. Oil seals may become worn or damaged due to improper installation, excessive main bearing clearances, excessive flywheel housing bore runout, grooved sealing surfaces on the crankshaft hubs or out of square installation. To prevent a repetition of any oil seal leaks, these conditions must be checked and corrected.

The maximum runout of the oil seal bore in the gear case cover or flywheel housing is 0.330 mm (.013 in.). The bore may be checked with a dial indicator mounted on the end of the crankshaft in a manner similar to the procedure for checking the flywheel housing concentricity. Refer to section 1.16.3.1. This check must be made with the flywheel housing or gear case cover in place on the engine and the oil seal removed.

Inspect the seal contact surface of the crankshaft for wear caused by the rubbing action of the oil seal, dirt buildup or by the fretting action of the flywheel. The crankshaft surface must be clean and smooth when a new wear sleeve and seal are installed.

1.9 CRANKSHAFT MAIN BEARINGS

The crankshaft main bearing shells are precision made and are replaceable without machining. They consist of an upper bearing shell seated in each cylinder block main bearing support and a lower bearing shell seated in each main bearing cap. See Figure 1–117.



1. Upper Bearing Shell
2. Crankshaft
3. Key
4. Lower Bearing Shell
5. No. 1 Main Bearing Cap
6. Flat Washer
7. Bolt
8. No. 4 Lower Bearing Shell
9. Upper Thrust Washer
10. No. 4 Upper Bearing Shell

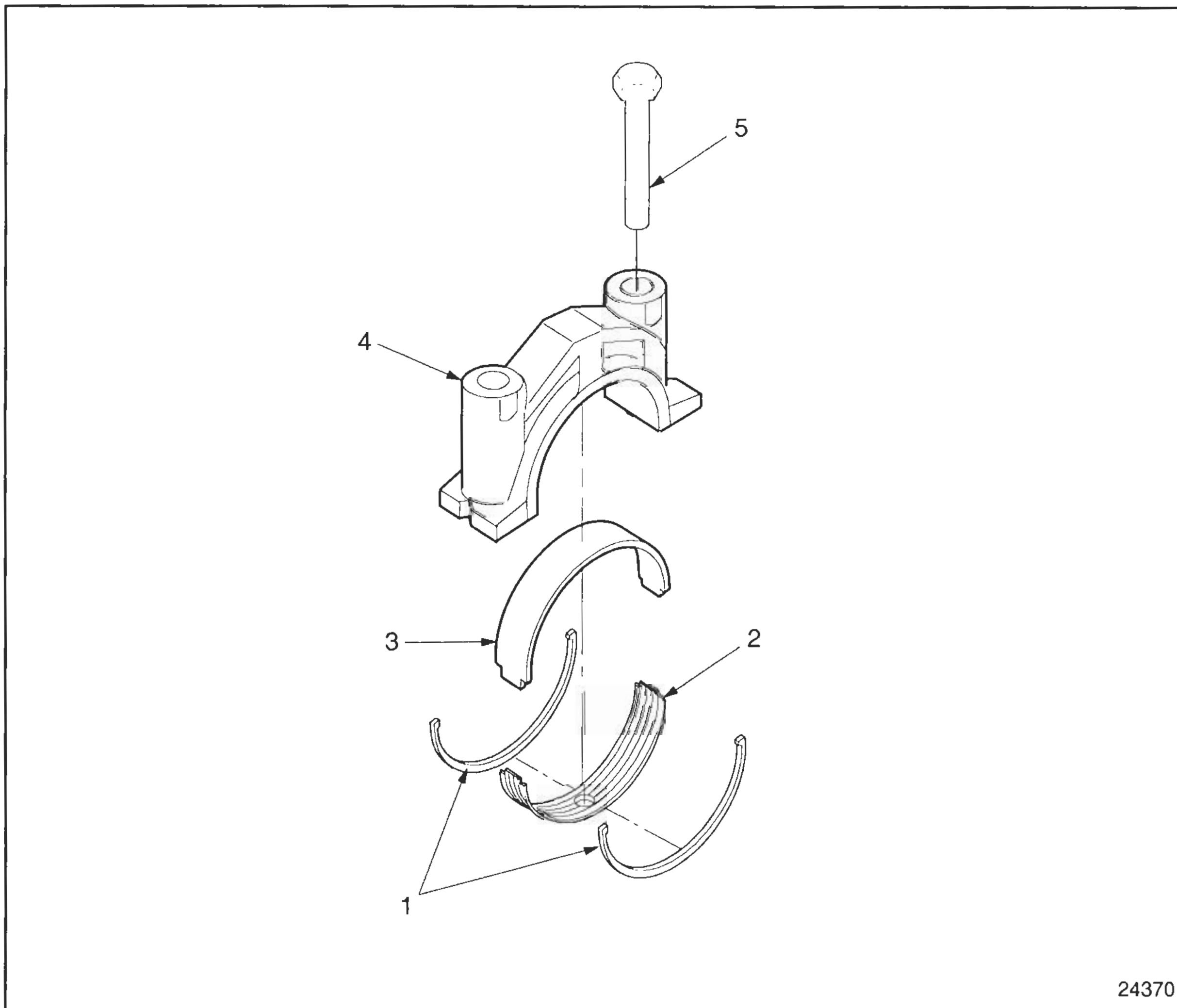
Figure 1–117 Main Bearings Caps, Bearing Shells and Crankshaft Thrust Washers

The upper and lower bearing shells are located in the respective block and bearing cap by a tang. The tang is located at the parting line at one end of each bearing shell. The tangs are off-set from center to aid correct insertion. Bearing shell sets are supplied as a matched assembly and should not be mixed.

A hole in each upper bearing shell registers with a vertical oil passage in the cylinder block. Lubricating oil, under pressure, passes from the cylinder block oil gallery by way of the bearing shells to the drilled passage in the crankshaft, then to the connecting rods and connecting rod bearings. The upper bearing shell is also grooved.

The lower main bearing shells have no oil holes or grooves. Therefore, the upper and lower main bearing shells must not be interchanged.

Thrust washers on each side of the No. 4 main bearing absorb the crankshaft thrust. The two-piece washers utilize locking tangs that register with locating notches in the bearing shell. See Figure 1-118.



1. Upper Thrust Washer
2. Upper No. 4 Bearing Shell
3. Lower No. 4 Bearing Shell
4. No. 4 Main Cap
5. Bolt

Figure 1–118 No. 4 Thrust Bearing Detail

The condition of the lower bearing shells may be observed by removing the main bearing caps.

1.9.1 Repair or Replacement of Crankshaft Main Bearings

To determine if repair is possible or replacement is necessary perform the following procedure. See Figure 1–119.

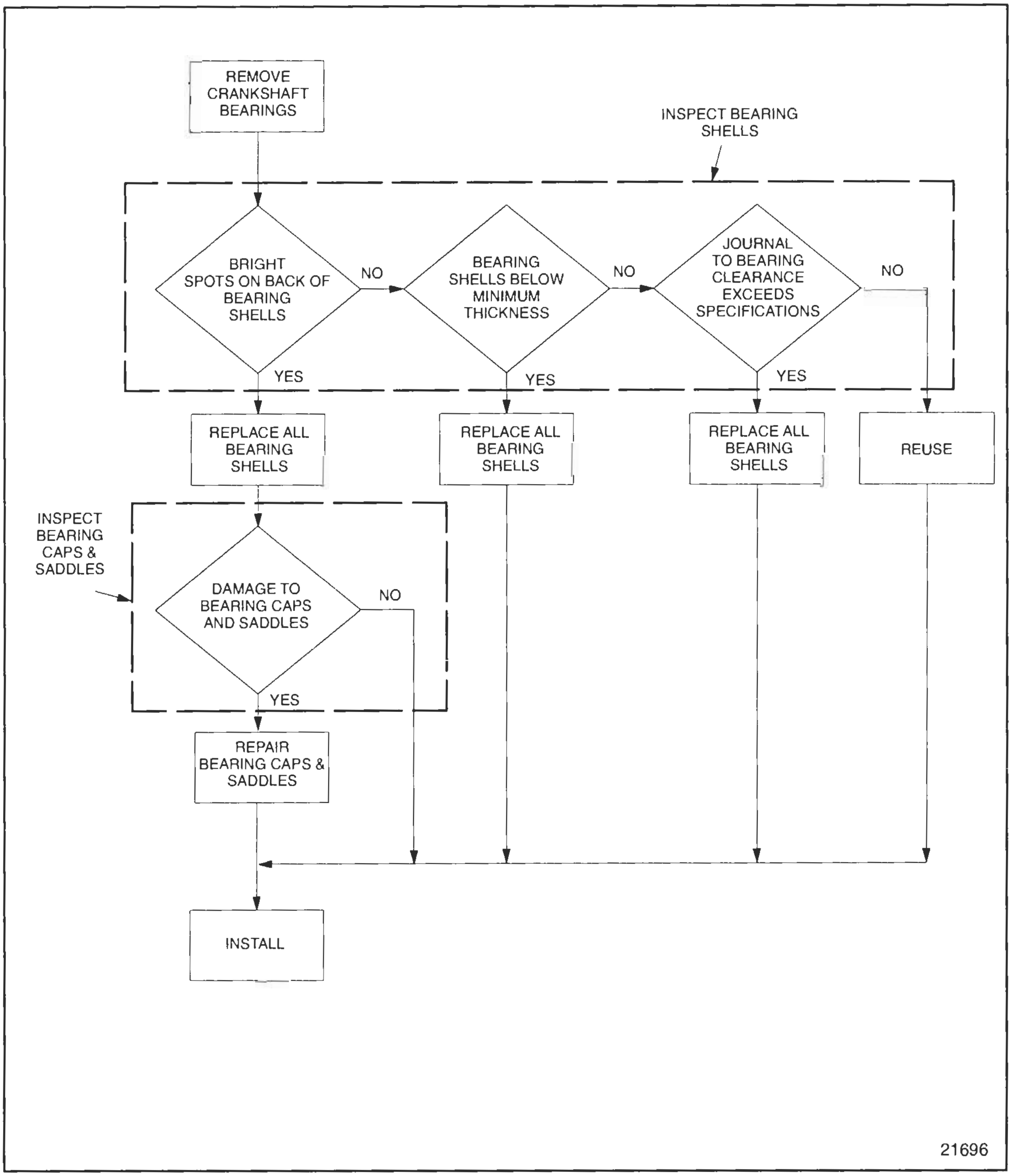


Figure 1–119 Flowchart for Repair or Replacement of Crankshaft Main Bearings

1.9.2 Removal of Main Bearing Shell

The main bearing caps are numbered consecutively, indicating their respective positions. When removed, the bearing caps (and the bearing shells, if they are to be reinstalled) must always be reinstalled in their original position.

1. Drain and remove the oil pan to expose the main bearing caps. Refer to section 3.9.2.

NOTE:
If shims are used between the oil pump and the cylinder block, save the shims so that they can be reinstalled in exactly the same location as removed. The shims are used to adjust the crankshaft timing gear–to–oil pump drive gear lash.

2. Remove the oil pump pickup and outlet pipes, and the oil pump. Refer to section 3.2.2.
3. Remove one bearing cap at a time and inspect the lower bearing shell. Refer to section 1.9.2.1.

NOTE:
Remove and reinstall both upper and lower bearing shells for each main journal being inspected before moving on to the next main journal. Never remove more than one main bearing cap at a time except for No. 4 and No. 5.

4. To remove the upper main bearing shells without crankshaft removal, it will be necessary to use the main bearing shell remover and installer tool set, J 36187–A. See Figure 1–120.

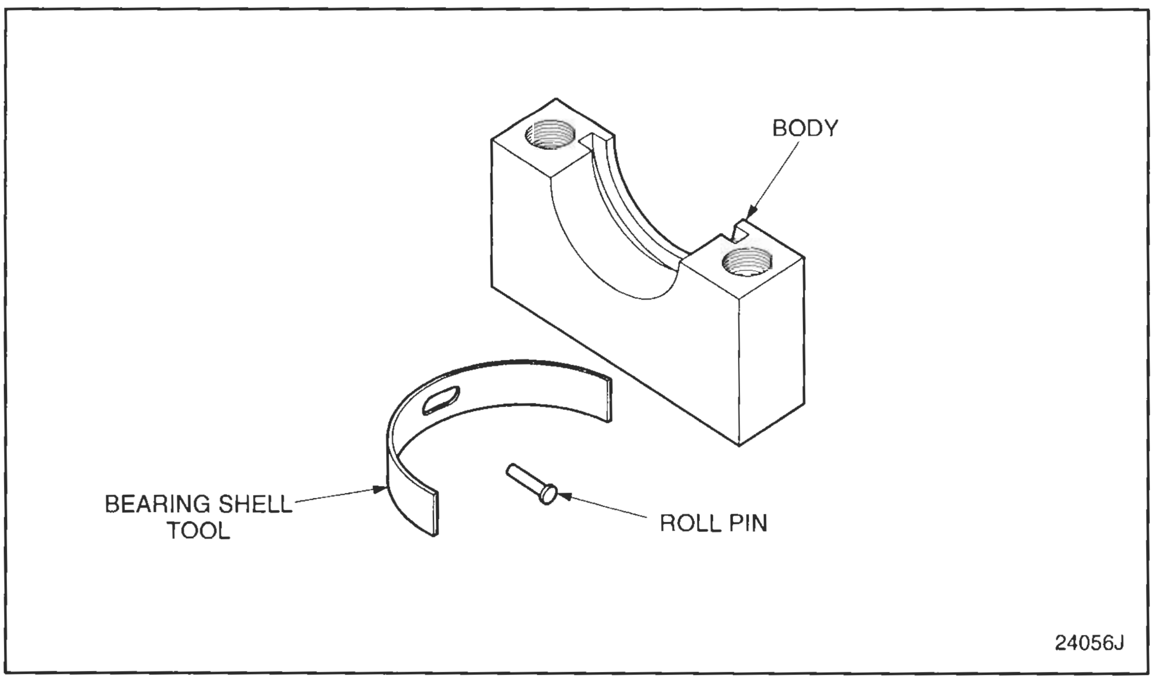


Figure 1–120 Main Bearing Shell Remover and Installer Tool Set

5. To bar the engine over, use the square hole in the middle of the crankshaft pulley, to position the crankshaft throw. Position the crankcase throw for the main bearing being worked on so that the oil delivery hole is pointing upward. See Figure 1-121.

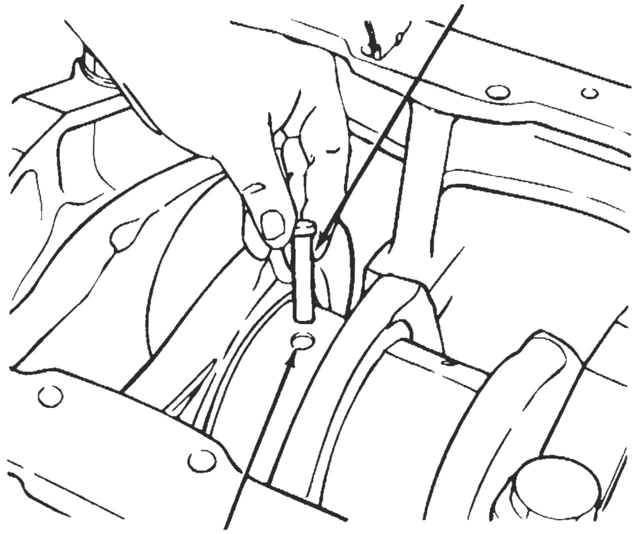


Figure 1-121 Upper Main Bearing Shell Removal and Roll Pin Installation

6. Install the roll pin to the oil delivery hole in the crankshaft journal. See Figure 1-121. If this operation is being performed in-frame, use petroleum jelly to retain the roll pin in the hole.
7. For the No. 4 main bearing journal, it will be necessary to install the lower main bearing thrust washers (previously removed) to the machined faces of the body from the tool kit. Stick the thrust washers to the main cap using petroleum jelly. Index the locating tangs on the thrust washers with the cut-outs on the bearing shell.
See Figure 1-122.

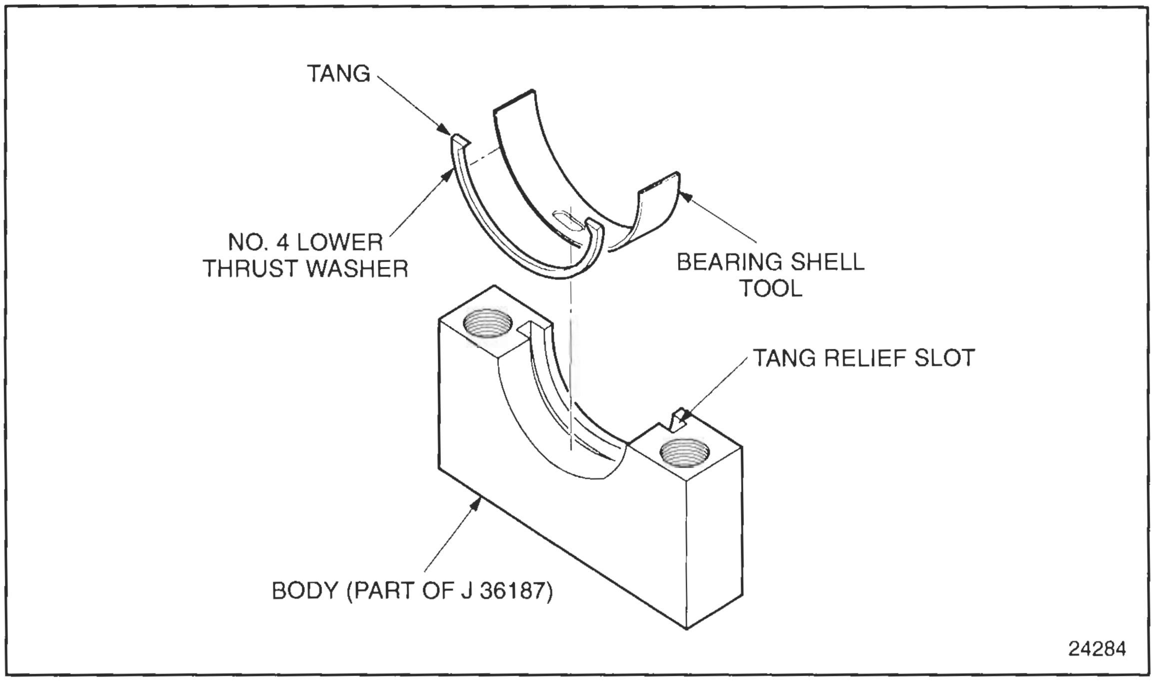


Figure 1–122 Upper Main Bearing Shell Removal–Tool Set–up

8. Using the main bearing cap bolts and washer removed from the engine, install the assembled main bearing cap remover and installer tool to the main bearing saddle being worked on. The word "Front" stamped on the tool must face the front of the engine. Be sure that the roll pin in the oil delivery hole registers with the cut–out section of the bearing shell tool before tightening the main bearing cap bolts. See Figure 1–123.

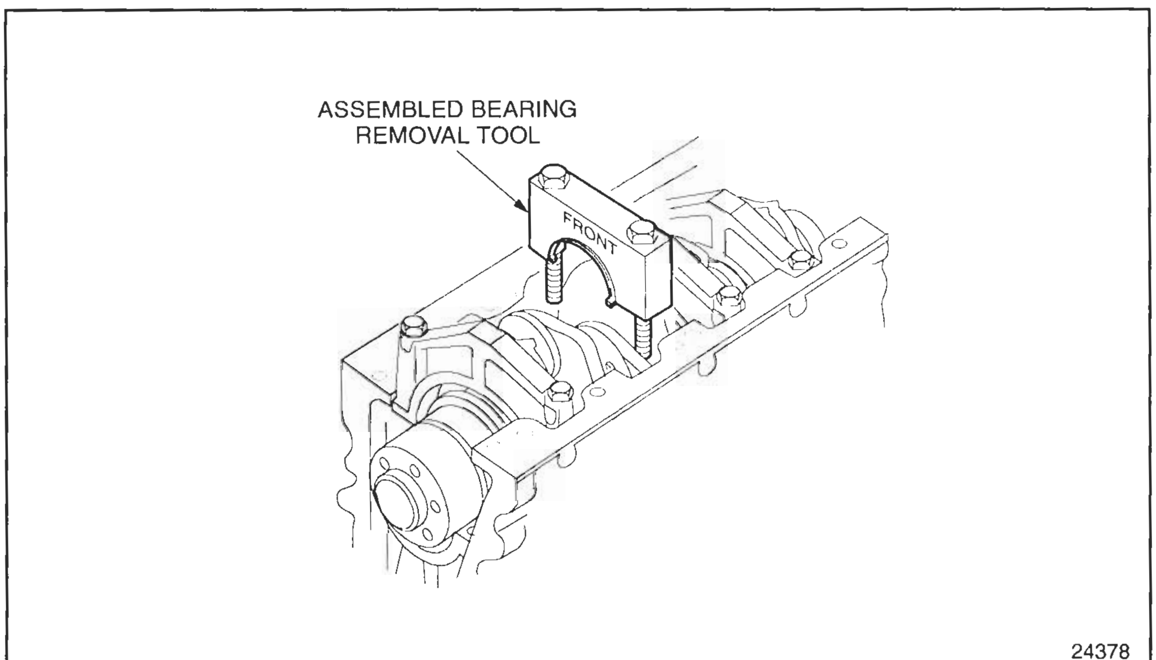


Figure 1–123 Upper Main Bearing Shell Remover Tool Installation

NOTE:
Only the No. 4 main bearing shell requires use of the thrust washers on the sides of the remover tool. For main bearings No. 1, 2, 3, and 5, it will not be necessary to install the thrust washers to the tool.

9. Tighten the main bearing cap bolts until they are snug 13–27 N·m (10–20 lb·ft) torque.
10. Using the square hole in the middle of the crankshaft pulley, bar the engine over in a clockwise direction when viewed from the front, approximately 180° until the tang of the upper main bearing contacts the block. This will roll the bearing shell tool (and the thrust washers for No. 4 main bearing) into the upper main bearing saddle.

NOTE:
Keep all bearing shells and thrust washers segregated by number, so that they may be reinstalled exactly as removed if the bearing shells are reused. Shells and washers may be marked with a permanent marker or equivalent. Do not punch mark or otherwise disturb the surface of the shells and washers to mark them.

11. Remove the main bearing cap tool from the saddle.
12. Remove the upper shell (and two thrust washers when working on No. 4 main) from the tool.
13. Inspect the bearing shells (and thrust washers for No. 4 main). Refer to section 1.9.2.1.
14. Install the upper main bearing to be used, in the main bearing installer and remover with the word "Front" facing the front of the engine. If the No. 4 main bearing is being done, install the thrust washers to the bearing. Refer to step 8. and refer to step 9. in this procedure.
15. Position the remover and installer with the bearings in the saddle being worked on and install the main bearing cap bolts and washers. Tighten the bolts until they are snug 13–27 N·m (10–20 lb·ft).
16. Using the square hole in the crankshaft pulley, bar the engine over slowly, in a counterclockwise direction, approximately 180°, until the bearing split line is even with the cap and block joint face. Care must be taken not to bar the engine over too far and damage the bearing tang.
17. Remove the bearing remover and installer assembly, J 36187-A.
18. Install the lower main bearing shell to be used, into the engine main bearing cap.
19. Coat the threads and underside of the heads of the main bearing cap bolts with International Compound No. 2. Position the main bearing cap, with bearing(s) in place into the saddle and install the bolts and washers. Rap the main bearing caps sharply with a fiber mallet or plastic hammer to insure the caps are fully seated. Tighten the bolts to 470–530 N·m (347–391 lb·ft) torque.

20. It will be necessary to reinstall the upper and lower main bearing shells (and the upper thrust washers for the No. 4 main) and the main bearing cap, for the bearings being inspected or replaced before proceeding to the next main bearing saddle. Refer to section 1.9.3.
21. Repeat this procedure for each main bearing saddle until all seven sets of main bearings have been removed and inspected or replaced.

NOTE:
No. 5 main bearing journal does not have an oil hole, so the bearing remover cannot be used at that position. The No. 5 upper main bearing should be removed with both No. 4 and No. 5 main bearing caps off. Using a suitable tool, push on the No. 5 upper bearing on the side opposite the tang and dislodge the bearing tang from the tang slot in the cylinder block. Carefully push/pull the bearing the rest of the way out, taking care not to damage the bearing shell. Rotate the crankshaft, and apply some pressure to the side of the bearing while rotating.

22. After removal, clean the bearings.

1.9.2.1 Inspection of Crankshaft Main Bearings

Bearing failures may result from deterioration (acid formation) or contamination of the oil or loss of oil. An analysis of the lubricating oil may be required to determine if corrosive acid and sulphur are present, which cause acid etching, flaking and pitting. Bearing seizure may be due to low oil or no oil.

Inspect the bearings for scoring, pitting, flaking, etching; or signs of overheating. The bearing overlay may develop minute cracks or small isolated cavities (checking) on the bearing surface during normal engine operation. These are characteristics of and are not detrimental to this type of bearing. They should not be replaced for these minor surface imperfections, since function of the bearings is in no way impaired and they will give many additional hours of trouble–free operation.

Inspect the backs of the bearing shells for bright spots, which indicate they have been moving in the bearing caps. If such spots are present, discard the bearing shells, and inspect the bearing caps and upper bearing saddles.

Measure the thickness of the bearing shells at point "C", 90° from the parting line. See Figure 1–124.

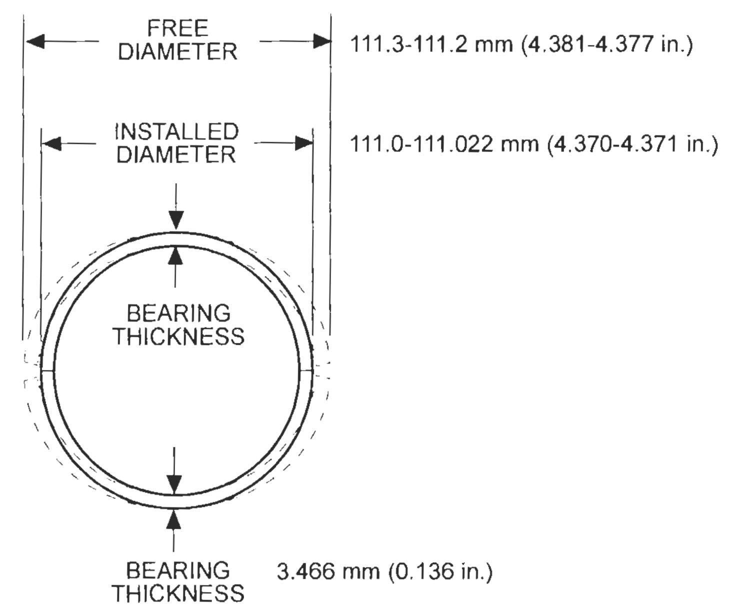


Figure 1–124 Main Bearing Measurements

A tool placed between the bearing shell and a micrometer, will give an accurate measurement. The bearing shell thickness will be the total thickness of the steel ball in the tool and the bearing shell, less the diameter of the ball. This is the only practical method for measuring the bearing thickness, unless a special micrometer is available for this purpose. The minimum thickness of a worn standard main bearing shell is 3.937 mm (.155 in.). If any of the bearing shells are thinner than this dimension, replace all of the bearing shells. A new standard bearing shell has a thickness of 3.962–3.980 mm (.1560–.1567 in.). If any bearing shell shows wear through the overlay across the width of the shell, all bearing shells must be replaced.

In addition to the thickness measurement, check the clearance between the main bearings and the crankshaft journals. This clearance may be determined with the crankshaft in place by means of a soft plastic measuring strip that is squeezed between the journal and the bearing as described in "Checking Bearing Clearance". Refer to section 1.A. With the crankshaft removed, measure the outside diameter of the crankshaft main bearing journals and the inside diameter of the main bearing shells when installed in place with the proper torque 470–530 N·m (347–391 lb·ft) torque on the bearing cap bolts. When installed, the bearing shells are 0.0254 mm (.001 in.) larger in diameter at the parting line than 90° from the parting line.

The bearing shells do not form a true circle out of the engine. When installed, the bearing shells have a squeeze fit in the main bearing bore and must be tight when the bearing cap is drawn down. This **crush** assures a tight, uniform contact between the bearing shell and bearing seat. Bearing shells that do not have sufficient crush will not have uniform contact, as shown by shiny spots on the back, and must be replaced. If the clearance between any crankshaft journal and its bearing shells exceeds 0.152 mm (.006 in.), all of the bearing shells must be discarded and replaced. This clearance is 0.040–0.126 mm (.0016–.005 in.) with new parts.

If installing new replacement bearings, it is very important to thoroughly inspect the crankshaft journals. Also, damaged bearings may cause bending fatigue and resultant cracks in the crankshaft. Refer to section 1.7.2.12.

Do not replace one main bearing shell alone. If one bearing shell requires replacement, install all new upper and lower shells. **Anytime a new or reground crankshaft is used, all new bearing shells must be used.**

NOTE:
Bearing shells are NOT reworkable from one undersize to another undersize under any circumstances.

Bearing shells are available in 0.250, 0.500 and 0.750 mm (approximately .010, .020 and .030 in.) undersize for service with reground crankshafts as listed in Table 1–6 to determine what size bearings are required. Be sure the correct bearing to journal clearance is maintained when using these parts.

Inspect the crankshaft thrust washers. If the washers are discolored or worn excessively, or if the crankshaft end play is excessive, replace the thrust washers. Inspect the crankshaft thrust surfaces. Refer to section 1.7. If, after dressing or regrinding the thrust surfaces, new standard size thrust washers do not hold the crankshaft end play within the specified limits, it may be necessary to install oversize thrust washers on one or both sides of the No. 4 main bearing. A new standard size thrust washer is 3.56–3.48 mm (.140–.137 in.) thick. Thrust washers are available in 0.125 and 0.250 mm (.005 and .010 in.) oversize.

1.9.3 Installation of Main Bearings Shells (Crankshaft Removed)

Install the main bearing shells as follows:

1. Check that all of the parts are clean and dry.
2. Apply clean engine oil 360° around each crankshaft main journal and install the upper main bearing shells to their respective saddles in the cylinder block. Note the locating tangs and be sure the oil holes register with the galleries in the cylinder block.
3. Be sure to install the drilled bearing shells in the cylinder block and the plain bearing shells in the bearing caps. The upper and lower main bearing shells are not alike; the upper shell is drilled for lubrication, the lower bearing shell is not. If they are not installed correctly, the oil flow to the bearings and to the upper end of the connecting rods will be blocked off. Used bearing shells must be reinstalled on the same journal from which they were removed.
4. Perform all of the steps under "Installation of Crankshaft." Refer to section 1.7.3. Be sure to check the main bearing clearances with plastic gaging strips. Refer to section 1.A.
5. Be sure to check the crankshaft end play. The minimum and maximum values are listed in Table 1–14.
6. Tighten all of the main bearing cap bolts to 470–530 N·m (347–391 lb·ft) torque.
7. Measure the main bearing bores with dial bore gage, J 5347–B. Refer to section 1.A for reuse and replacement guidelines. The minimum and maximum values are listed in Table 1–16.

1.10 GEAR CASE COVER

The gear case cover and gear case housing bolt together at the front of the engine to form a sealed compartment for the engine gear train. See Figure 1–125.

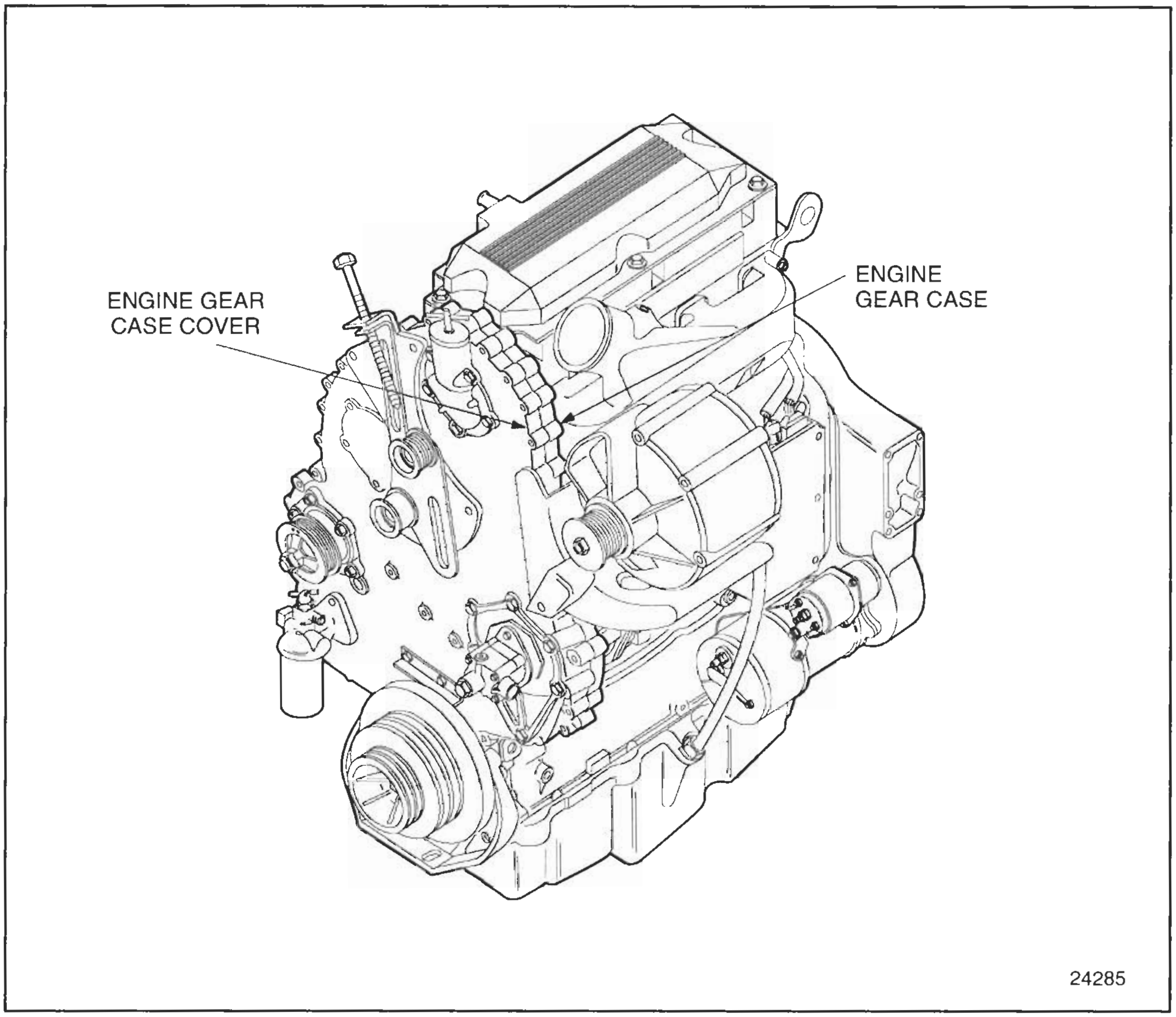


Figure 1–125 Engine Gear Case and Cover

The gear case cover also serves as a retainer for the crankshaft front oil seal. See Figure 1–126.

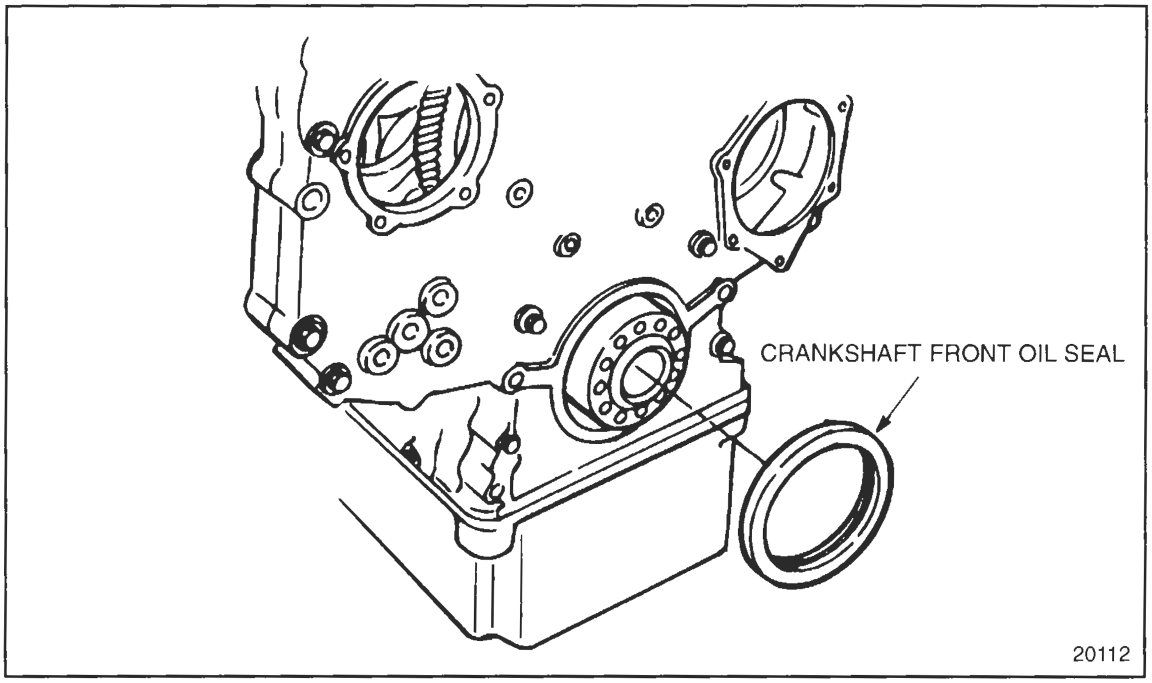


Figure 1–126 Crankshaft Front Oil Seal

Several components that are mounted to the gear case cover include the water pump, accessory drive assembly, and fan support bracket. See Figure 1–127.

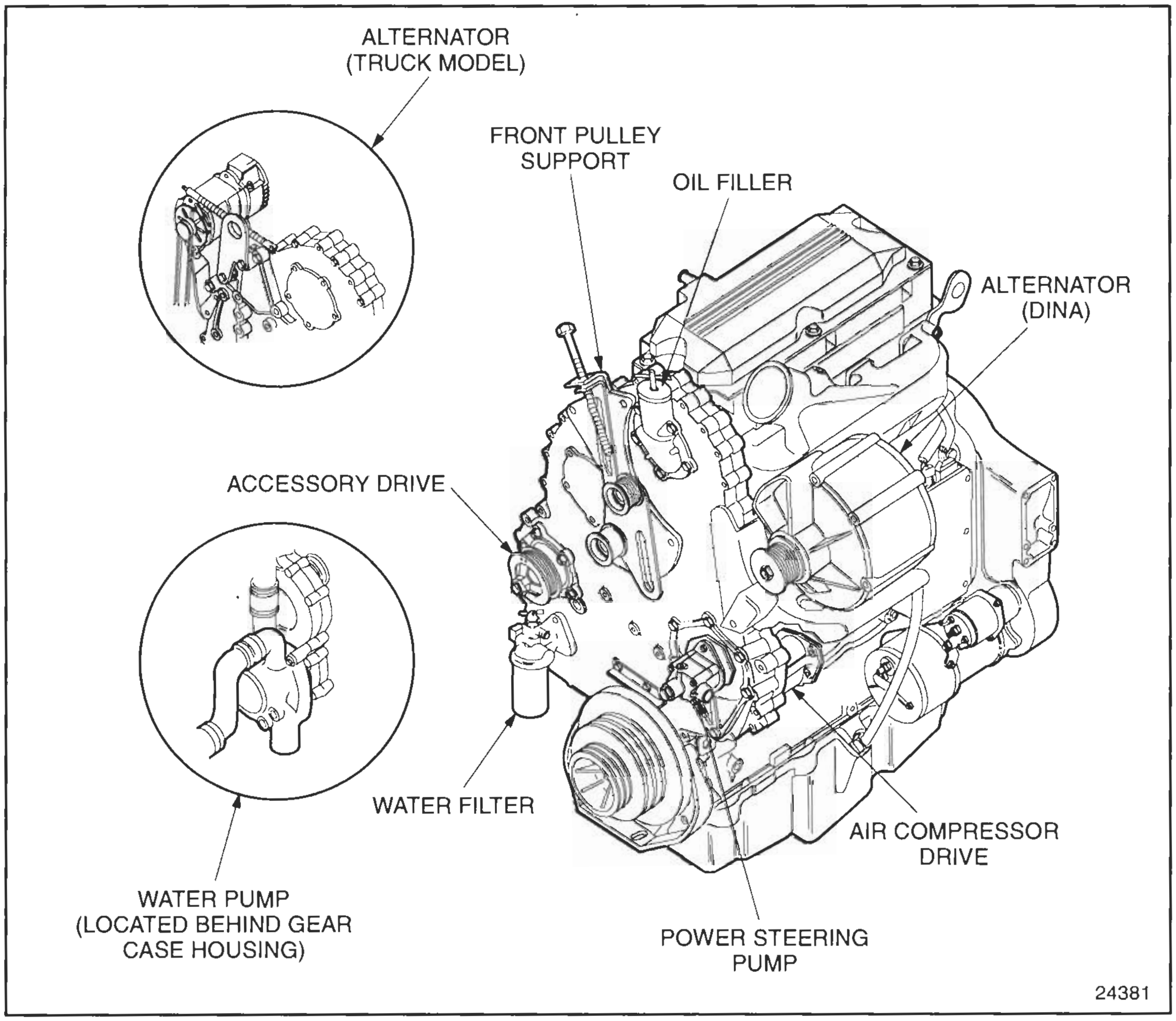


Figure 1–127 Gear Case Cover–mounted Components

The front engine support is bolted to the front of the gear case cover, directly behind the crankshaft pulley and vibration damper. See Figure 1–128.

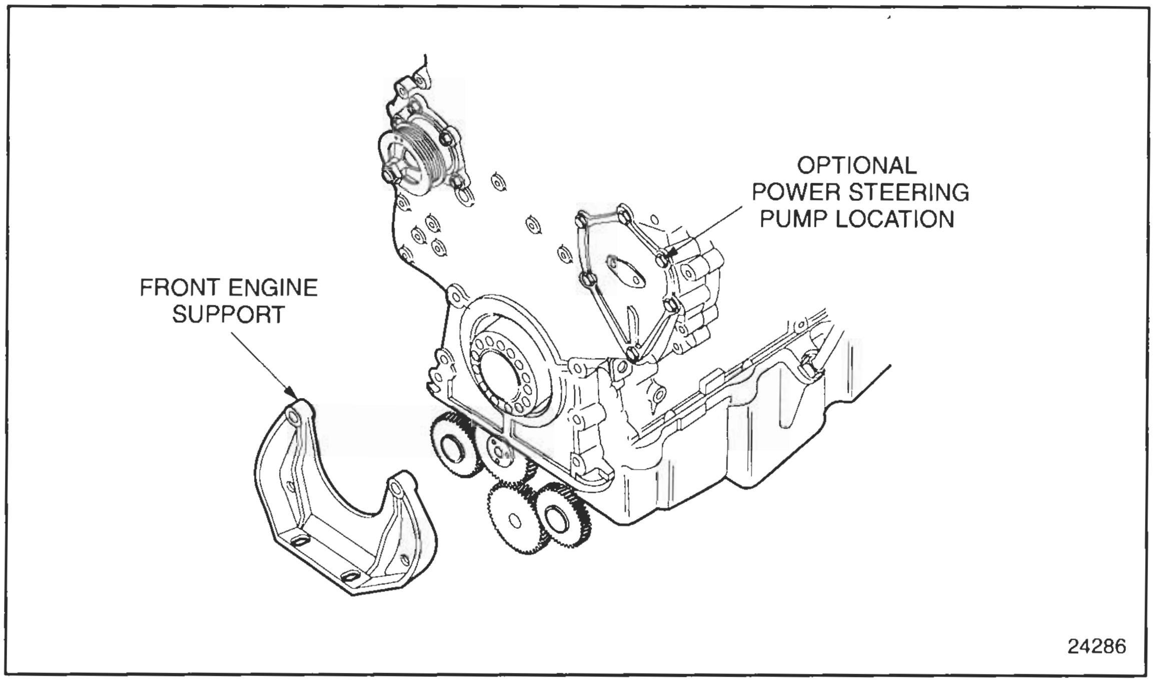


Figure 1–128 Typical Front Engine Support

Several access covers are provided on the gear case cover for service of the engine without removing the gear case cover. Removal of the camshaft drive gear access cover will allow the removal of the camshaft drive gear–to–camshaft bolt for camshaft and/or cylinder head removal without removing the gear case cover. See Figure 1–129.

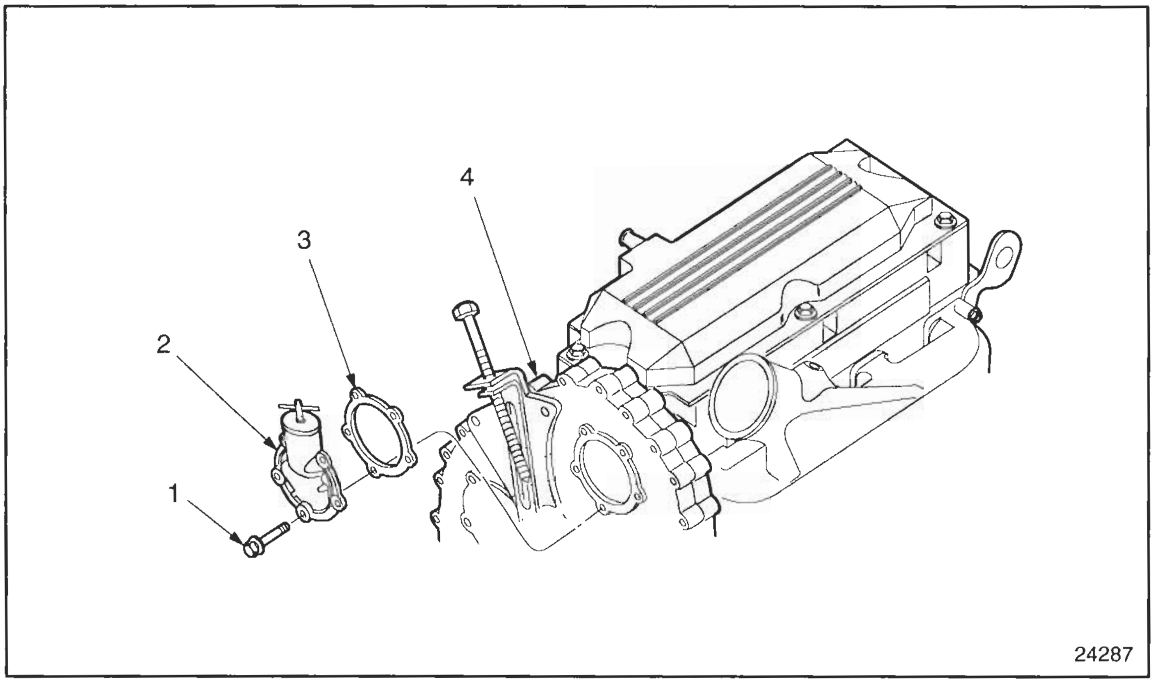


Figure 1–129 Camshaft Drive Gear Access Cover

The fan support bracket includes the access cover for the adjustable idler gear. See Figure 1–130.

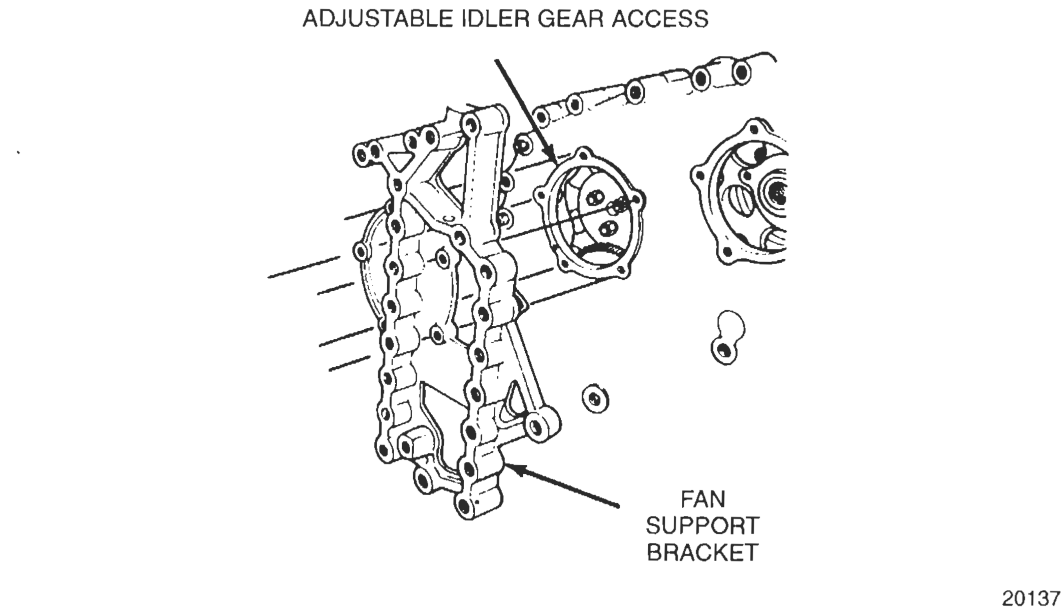


Figure 1–130 Fan Support Bracket for Truck Models

With the fan support bracket and the camshaft drive gear access cover removed, the gear lash between the adjustable idler gear and the camshaft drive gear can be measured and adjusted. Refer to section 1.21.2.1.

On vehicles without power steering, an access cover is provided for inspection of the air compressor drive gear. See Figure 1–131.

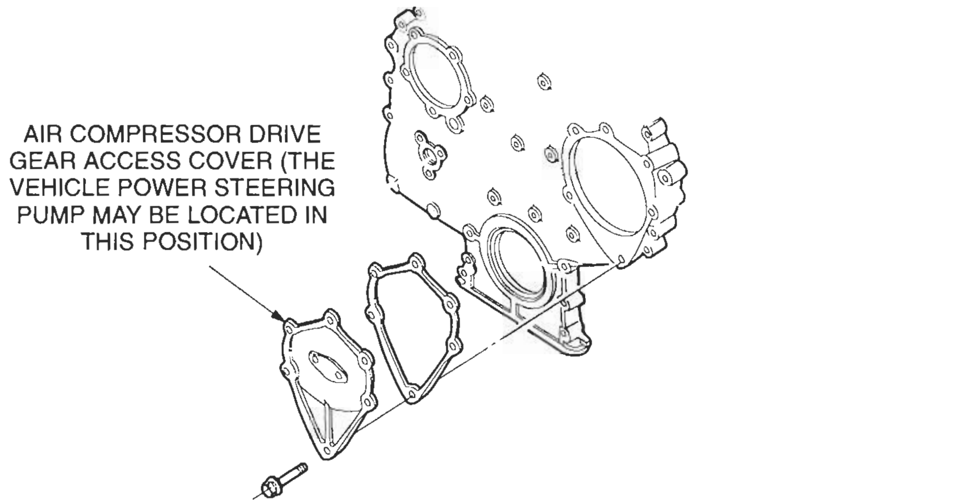


Figure 1–131 Air Compressor Drive Gear Access Cover

On some vehicles equipped with power steering, the power steering hydraulic pump is mounted to the gear case cover in the place of the access cover, and is driven by a short coupling that fits in the splined hole in the center of the air compressor drive gear. The pump is installed with a gasket.

1.10.1 Repair or Replacement of Gear Case Cover

To determine if repair is possible or replacement is necessary perform the following procedure. See Figure 1–132.

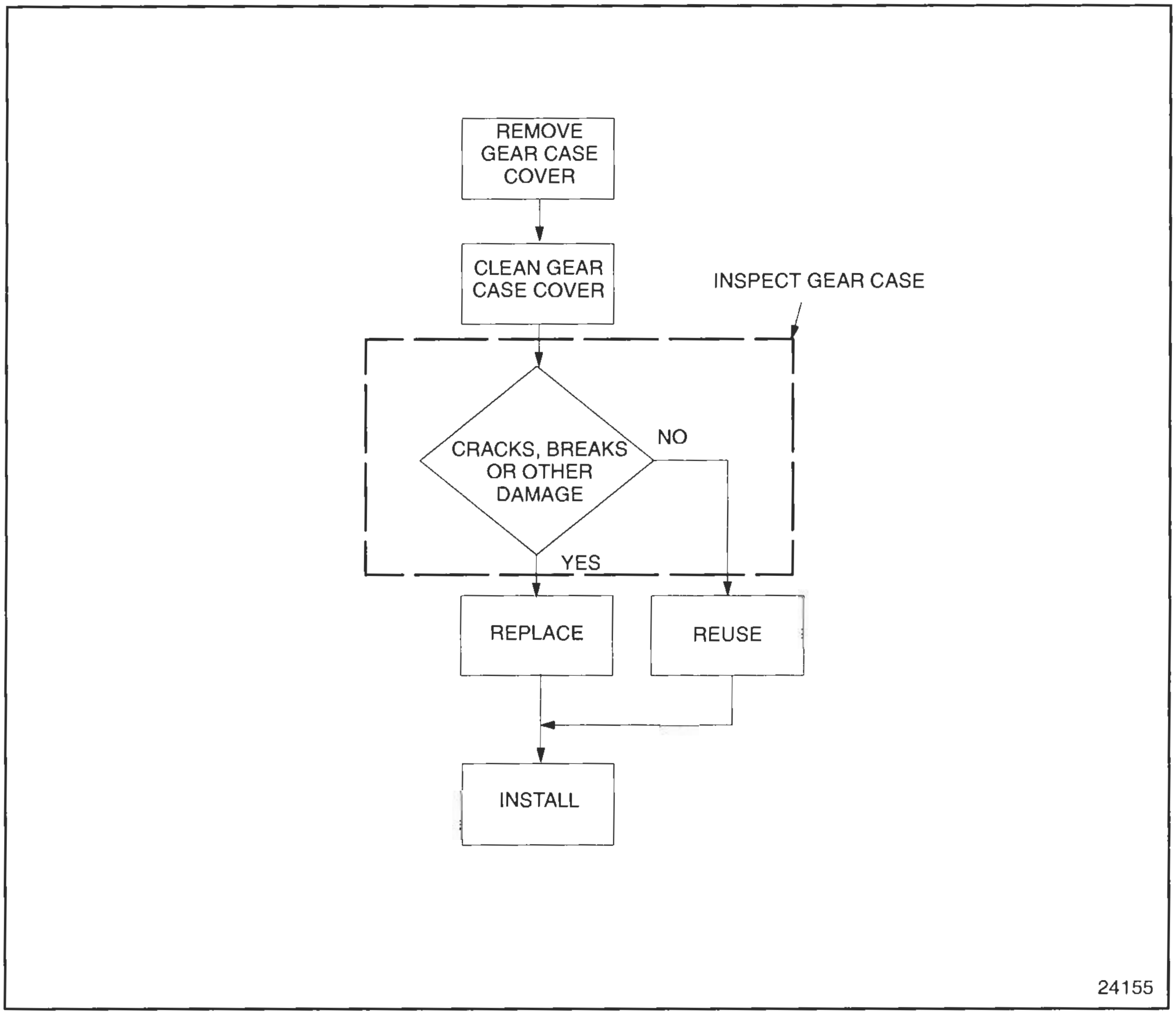


Figure 1–132 Flowchart for Repair or Replacement of Gear Case Cover

1.10.2 Removal of Gear Case Cover

With the engine mounted on an overhaul stand. Remove the gear case cover as follows:

1. Drain the engine oil and remove the engine oil pan. Refer to section 3.9.2.
2. Loosen the fan hub mounting bolts. Loosen the fan adjusting bolt. Back the adjuster off far enough to remove the drive belts. Remove the fan and fan hub assembly. Refer to section 4.5.2.
3. Loosen the alternator mounting bolts. Remove the alternator drive belts, alternator, and mounting brackets (if so equipped). See Figure 1–133.

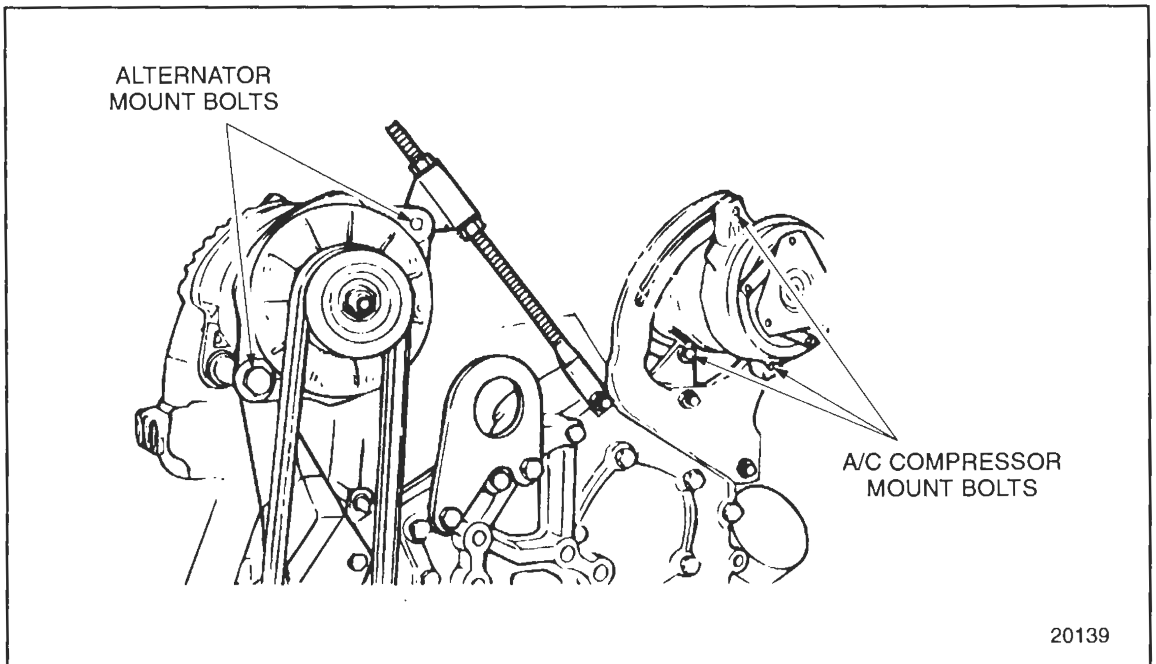


Figure 1–133 Alternator and Related Parts

4. Loosen the air conditioner compressor and mounting brackets (if so equipped).
5. Remove the water pump assembly. Refer to section 4.2.2.

6. Remove the power steering pump (if so equipped).

NOTICE:
Damage to the internal components may result. The oil pan cannot be used to support the front of the engine in a vehicle, as its thermoplastic construction will not support the weight.

7. Remove the crankshaft pulley. Refer to section 1.13.2.

NOTE:
Do not hit the face of the damper to loosen it.

8. Remove the vibration damper. Refer to section 1.12.2.
9. Loosen and remove the four bolts securing the front engine mount to the gear case cover. Remove the front engine mount.
10. Loosen and remove the five bolts that secure the accessory drive assembly to the gear case cover.
11. Remove the accessory drive assembly by pulling it straight out of the gear case cover to avoid damaging the rubber O-ring. See Figure 1-134.

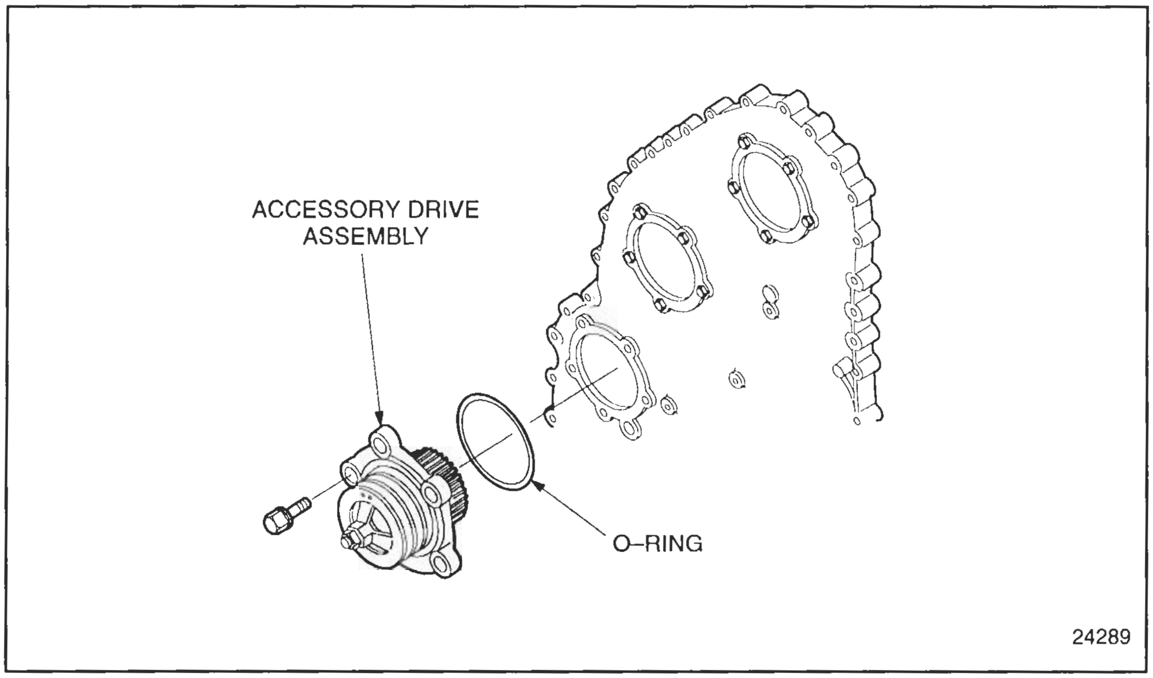


Figure 1–134 Accessory Drive Assembly

12. There are a total of 34 bolts that secure the gear case cover to the gear case. Bolts 17, 18, 19 and 20 were removed with the front engine mount. Bolts F1 through F5 were removed in a previous step; refer to step 11. Loosen and remove bolts 1 through 16, 21, 22. See Figure 1-135.

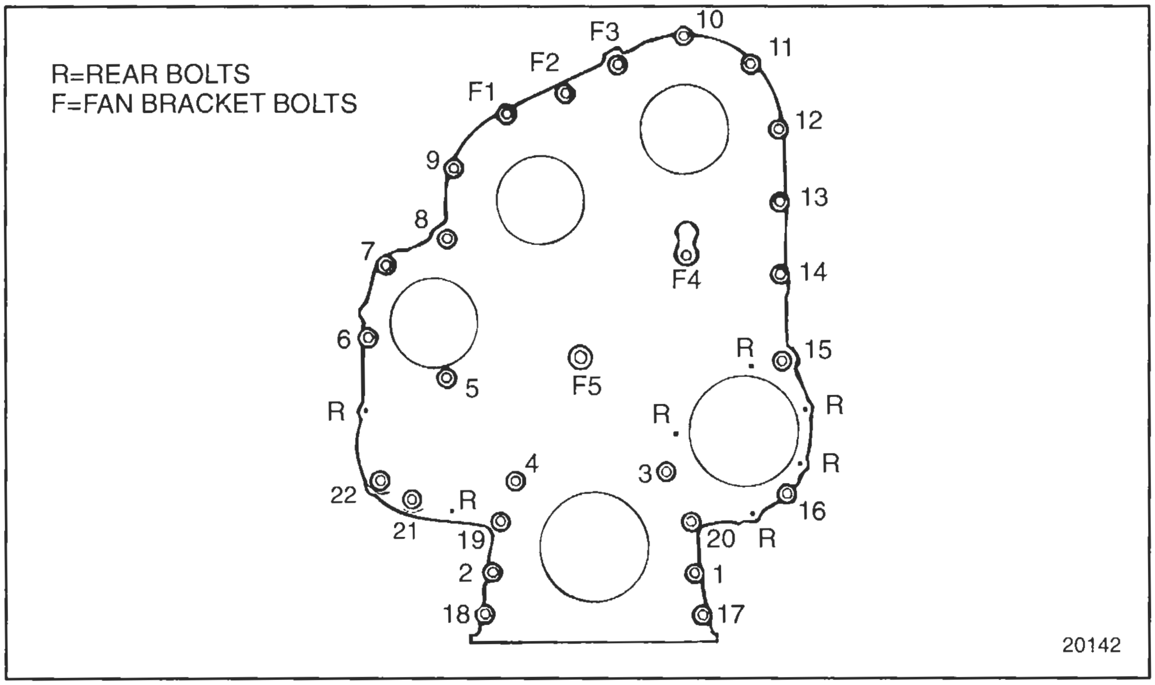


Figure 1–135 Gear Case Cover Bolt Arrangement (Front)

[a] Remove the SRS. Refer to section 2.15.2. Loosen and remove the six bolts on the back of the gear case on the intake side of the engine located around the air compressor drive assembly. See Figure 1–136. Remove the air compressor drive assembly.

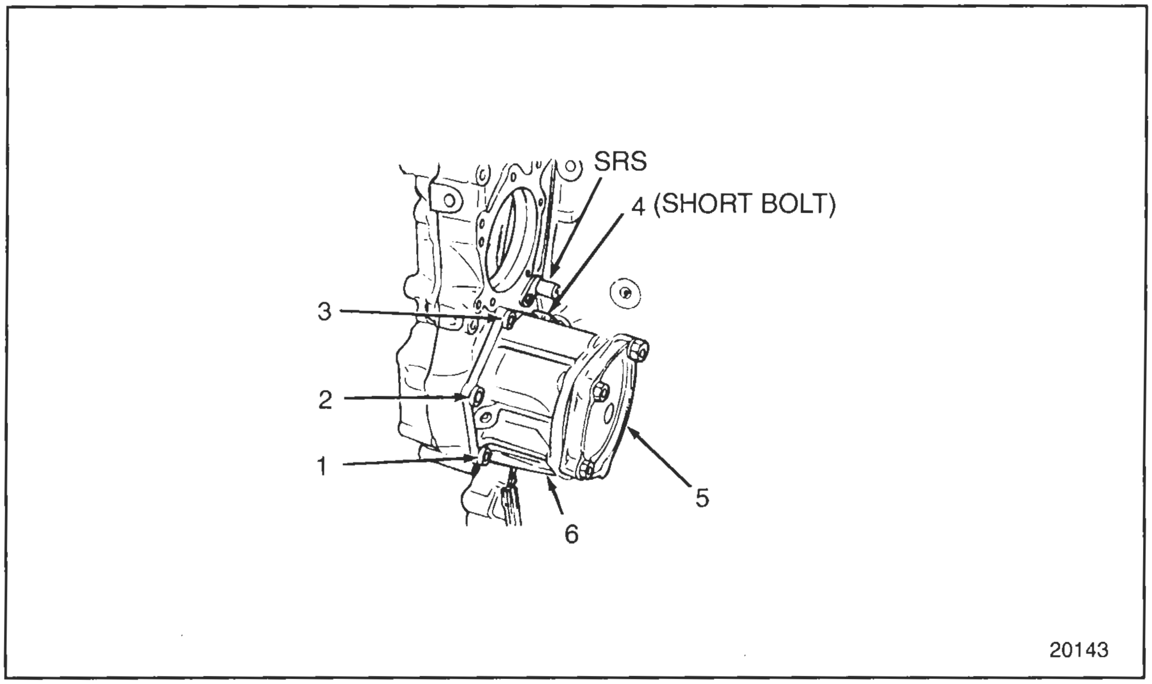


Figure 1–136 Gear Case Cover Bolt Arrangement (Left Rear)

[b] Loosen and remove the bolts on the back of the gear case on the water pump (right) side of the engine. See Figure 1–137.

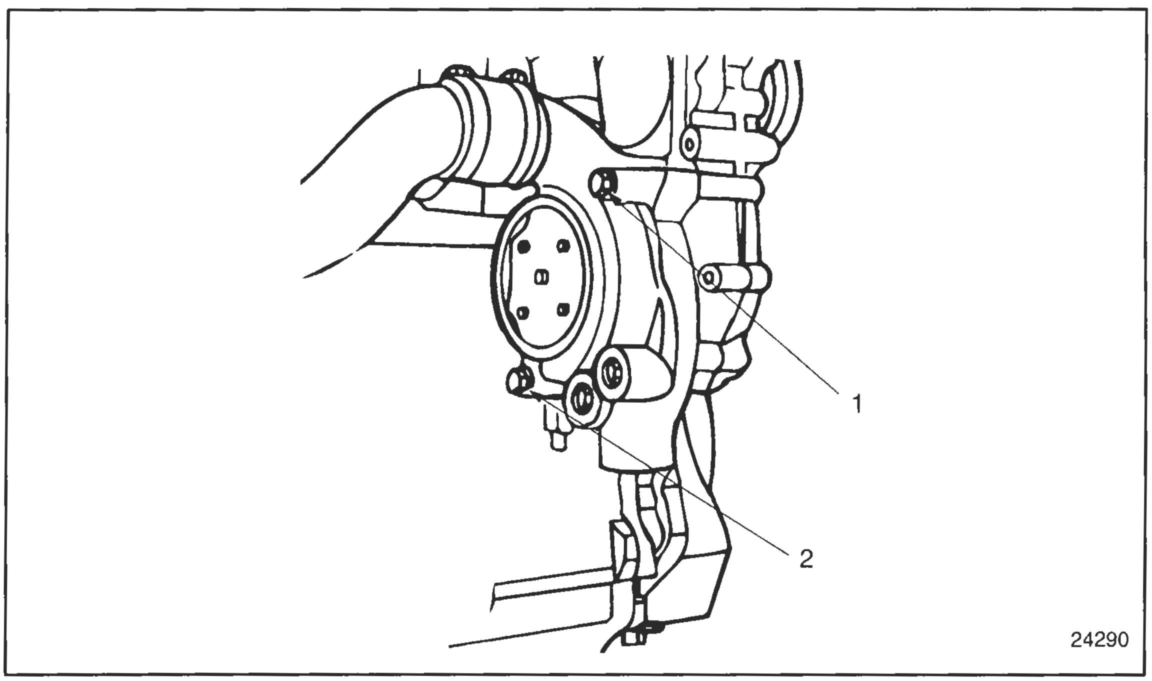


Figure 1–137 Gear Case Cover Bolt Arrangement (Right Rear)

13. Support the gear case cover with a suitable lifting device, using the front engine lift bracket. See Figure 1–138.

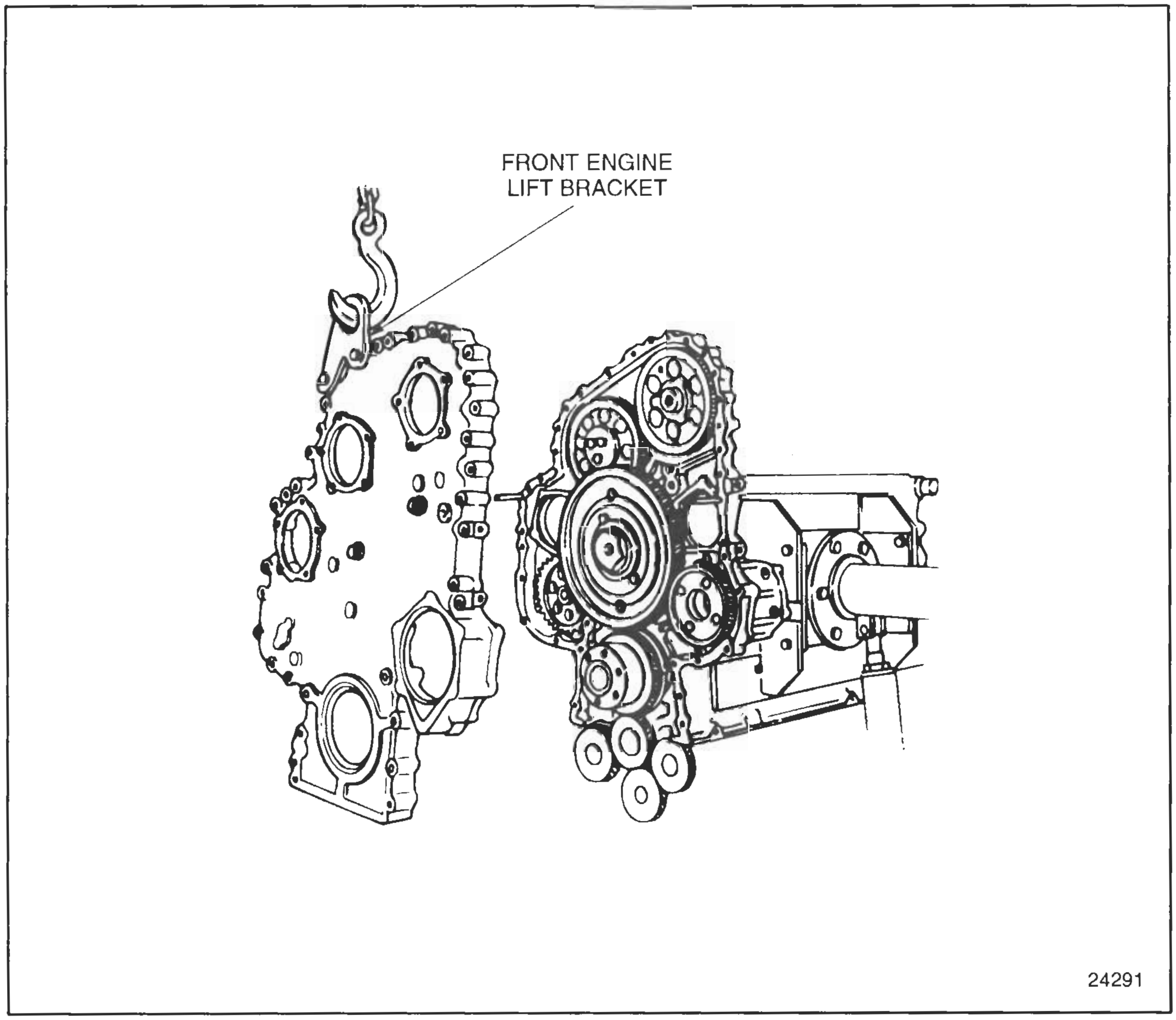


Figure 1–138 Engine Gear Case Cover Removal

NOTE:
There is a rubber O–ring installed between the center of the bull gear hub and the gear case cover. The ring may adhere to the cover when it is removed. Be sure the ring is not lost. See Figure 1–139.

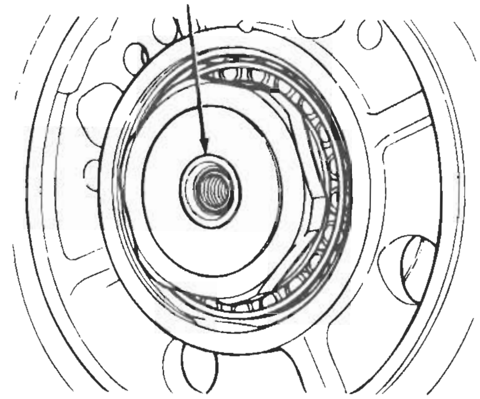


Figure 1–139 Bull Gear O–ring

14. Tap the gear case cover with a fiber mallet or plastic hammer to loosen it from the gear case. Remove the engine gear case cover.

1.10.2.1 Inspection of Gear Case Cover

Inspect the gear case cover as follows:

1. Clean all of the old gasket sealer from the mating surfaces of the gear case and gear case cover. Refer to section "Gasket Eliminator Removal" in the first section of this manual.
2. Clean the gasket material from the mating surfaces of any components or access covers that were removed from the gear case cover, and the gear case cover itself.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

3. Clean all of the removed parts except the electrical components with clean fuel oil and dry with compressed air.

NOTE:
Any time the gear case cover is removed, the crankcase oil seal must be replaced. Install the new front oil seal after the gear case cover has been installed to the engine.

4. If necessary, remove the crankshaft front oil seal at this time. Refer to section 1.8.2. Inspect the gear case cover for stress cracks or breaks in the casting. Repair or replace as necessary.
5. Inspect all O-rings for signs of dryness or splitting. Replace as necessary.

1.10.3 Installation of Gear Case Cover

Perform the following steps for gear case installation:

NOTE:
Gasket eliminator cures with the absence of air. The length of time between gear case cover installation and torquing of the bolts that secure the gear case cover to the gear case should be kept to a minimum.

1. Apply a continuous 1/16 in. bead of gasket eliminator PT-7276 (Loctite 51580) or equivalent to the mating surface of the gear case.
2. Install two guide studs, J 36107, to the gear case. See Figure 1-140.

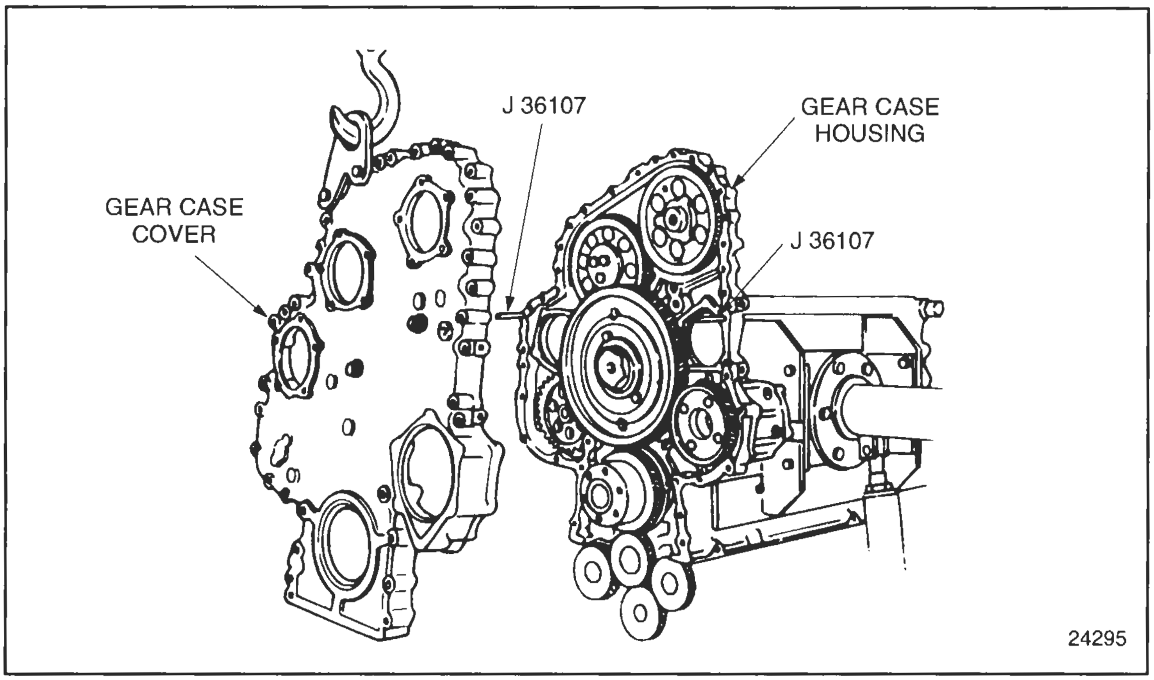


Figure 1-140 Gear Case Cover Locating Dowels

3. Support the gear case cover with a suitable lifting device, using the front engine lift bracket. Position the gear case cover on the guide studs and slide it forward. Index the two dowels in the gear case. See Figure 1–140.
4. There are 34 bolts that secure the gear case cover to the gear case (including five for the fan support bracket). Install them as follows:

NOTICE:
With gasketless parts such as the gear case cover, the torque values and tightening sequences are critical to prevent parts warpage.

[a] Install the shorter bolts, No. 1 through 16, 21, 22, in various locations at the front of the gear case cover. Tighten them finger tight. See Figure 1–141. Remove the guide studs when installing bolts 7 and 14.

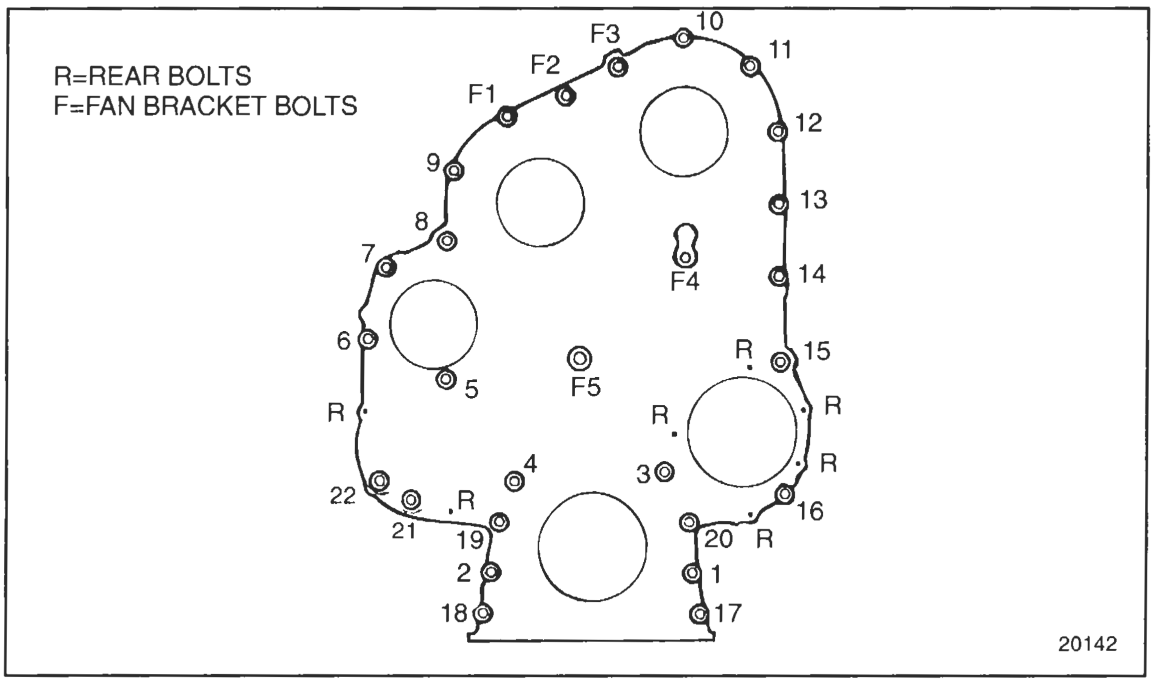


Figure 1–141 Gear Case Cover Bolt Torque Sequence (Front)

[b] Tighten bolts 1 through 16, 21, 22, to 58–73 N·m (43–54 lb·ft) torque.

[c] Install the front engine mount to the gear case cover. Install the four, longer, front engine mount–to–gear case cover bolts, finger tight.

[d] Tighten bolts 17, 18, 19 and 20 to 160–200 N·m (118–148 lb·ft) torque. See Figure 1–141.

[e] Bolts F1 through F5 are fan support bracket bolts. Install the fan support bracket and tighten bolts F1, F2 and F3 to 58–73 N·m (43–54 lb·ft). Tighten bolts F4 and F5 to 160–200 N·m (118–148 lb·ft).

[f] Install the six bolts on the intake (left) side of the engine around the air compressor drive. Tighten the bolts to 58–73 N·m (43–54 lb·ft) torque, using the sequence. See Figure 1–142. Install the SRS to the gear case; refer to section 2.15.3.

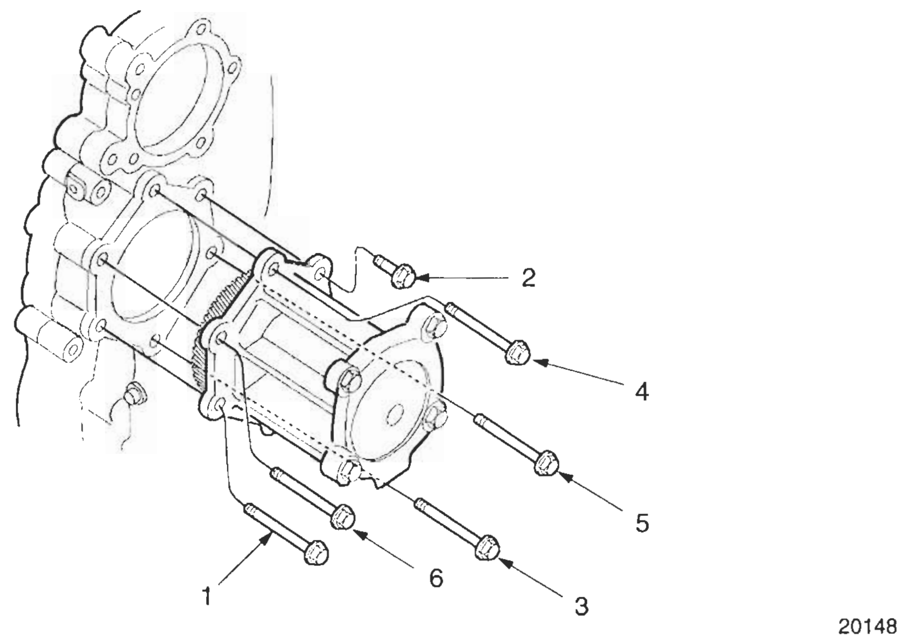


Figure 1–142 Gear Case Cover Bolt Torque Sequence (Left Rear)

[g] Install the bolts on the exhaust (right) side of the engine. Tighten the bolts to 58–73 N·m (43–54 lb·ft) torque. See Figure 1–143.

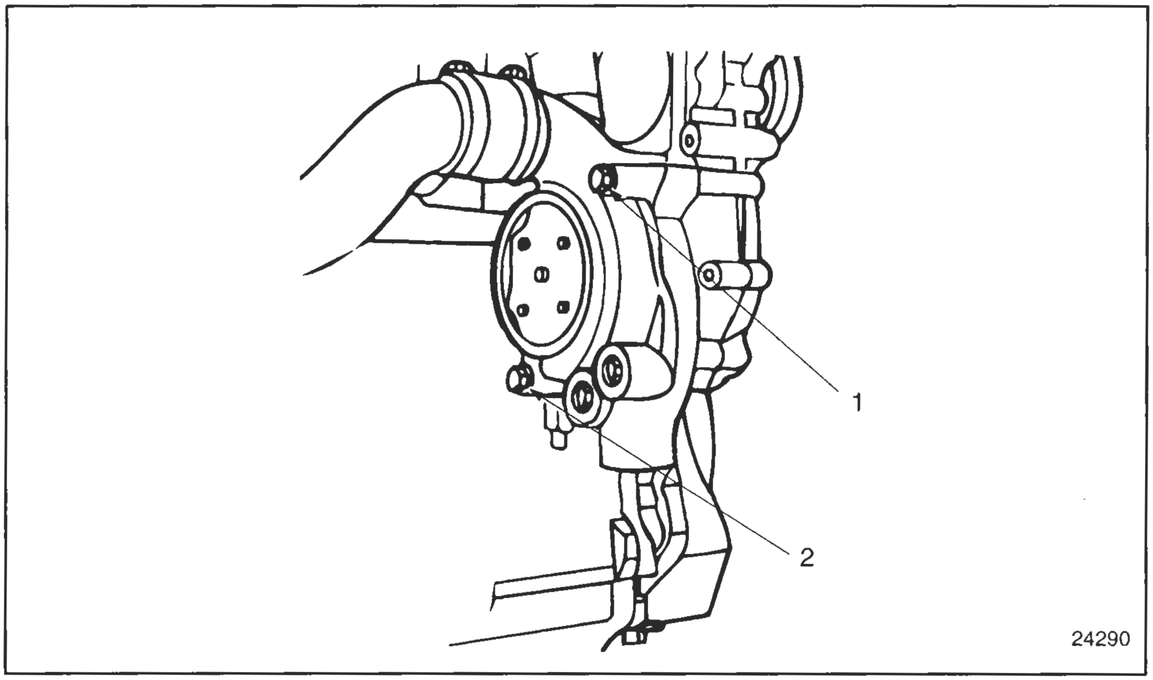


Figure 1–143 Gear Case Cover Bolt Torque Sequence (Right Rear)

5. Install a new crankshaft front oil seal. Refer to section 1.8.
6. Install the accessory drive assembly to the gear case. Refer to section 1.28.5. Tighten the bolts to 30–38 N·m (22–28 lb·ft) torque, using the sequence. See Figure 1–144.

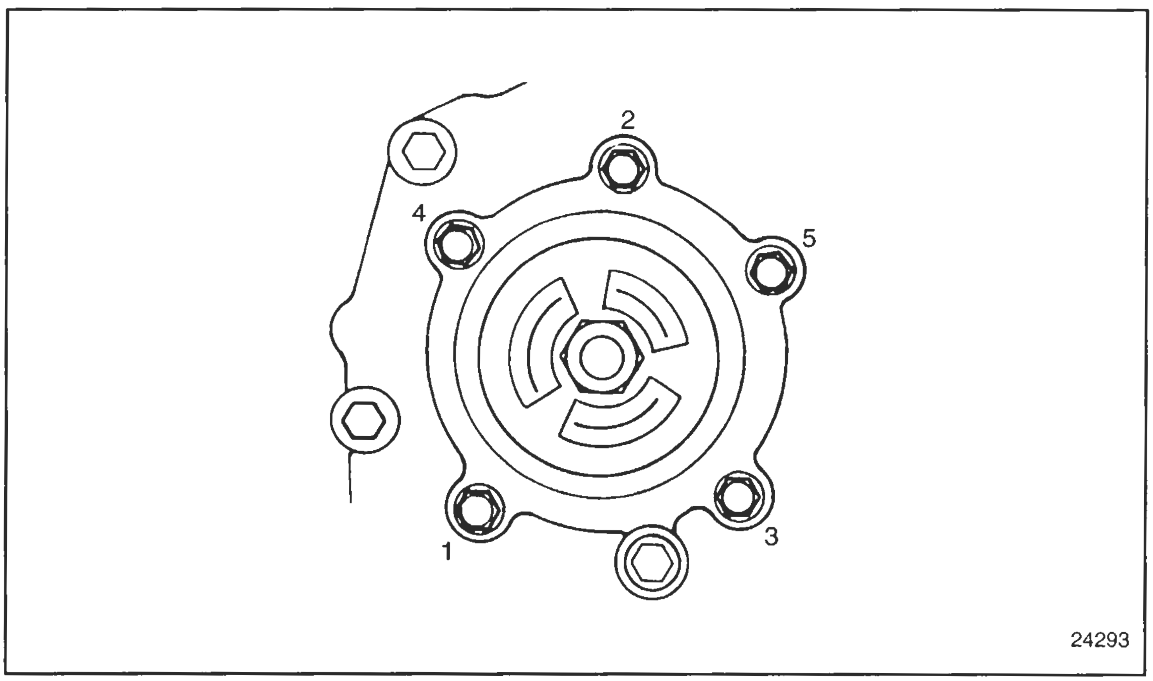


Figure 1–144 Accessory Drive Assembly Bolt Torque Sequence

7. Install the vibration damper to the crankshaft. Refer to section 1.12.3.
8. Install the crankshaft pulley to the end of the crankshaft. Refer to section 1.13.3.
9. Tighten the six pulley bolts to 182–210 N·m (134–155 lb·ft) torque. Mark the first bolt and work in a clockwise direction.
10. Install the water pump assembly. Refer to section 4.2.7.
11. Install a new O-ring between the power steering pump cover and the gear case (if so equipped). Install the power steering pump cover to the gear case cover with the six bolts. Tighten the bolts progressively in a star-shaped pattern to draw the power steering pump in evenly. Tighten the bolts to 30–38 N·m (22–28 lb·ft) torque, using a star-shaped pattern.
12. Insert a new gasket between the camshaft drive gear access cover and the gear case cover. Install the camshaft drive gear access cover to the gear case cover. Tighten the bolts to 30–38 N·m (22–28 lb·ft) torque, using the tightening sequence. See Figure 1–145.

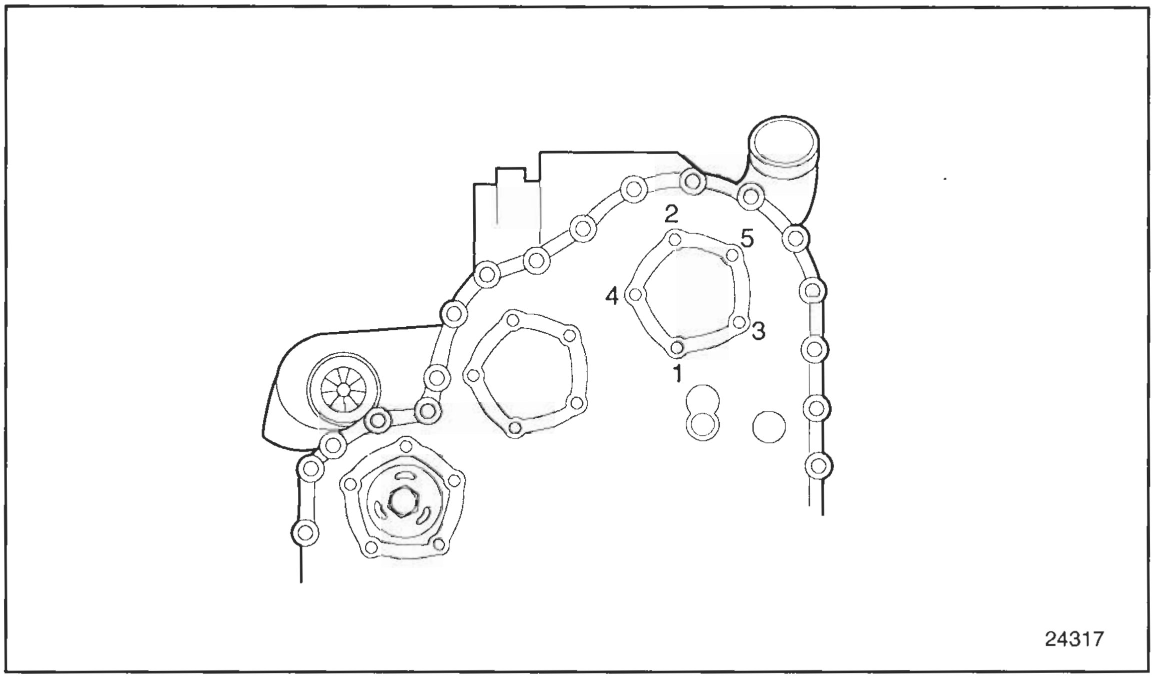


Figure 1–145 Access Cover Bolt Torque Sequences

13. Install the air conditioner compressor and brackets. Install the air conditioner compressor drive belt.
14. Install the alternator and brackets. Install the alternator drive belts.
15. Adjust the alternator and air conditioner compressor drive belts to the specifications. Refer to section 13.5.7.
16. Install the engine oil pan and fill the crankcase. Refer to section 13.5.1.

1.11 GEAR CASE

The gear case housing is constructed of cast iron, with machined mating surfaces, and is bolted to the front of the engine cylinder block. The gear case and gear case cover are bolted together to provide a sealed compartment for the engine gear train. See Figure 1–146.

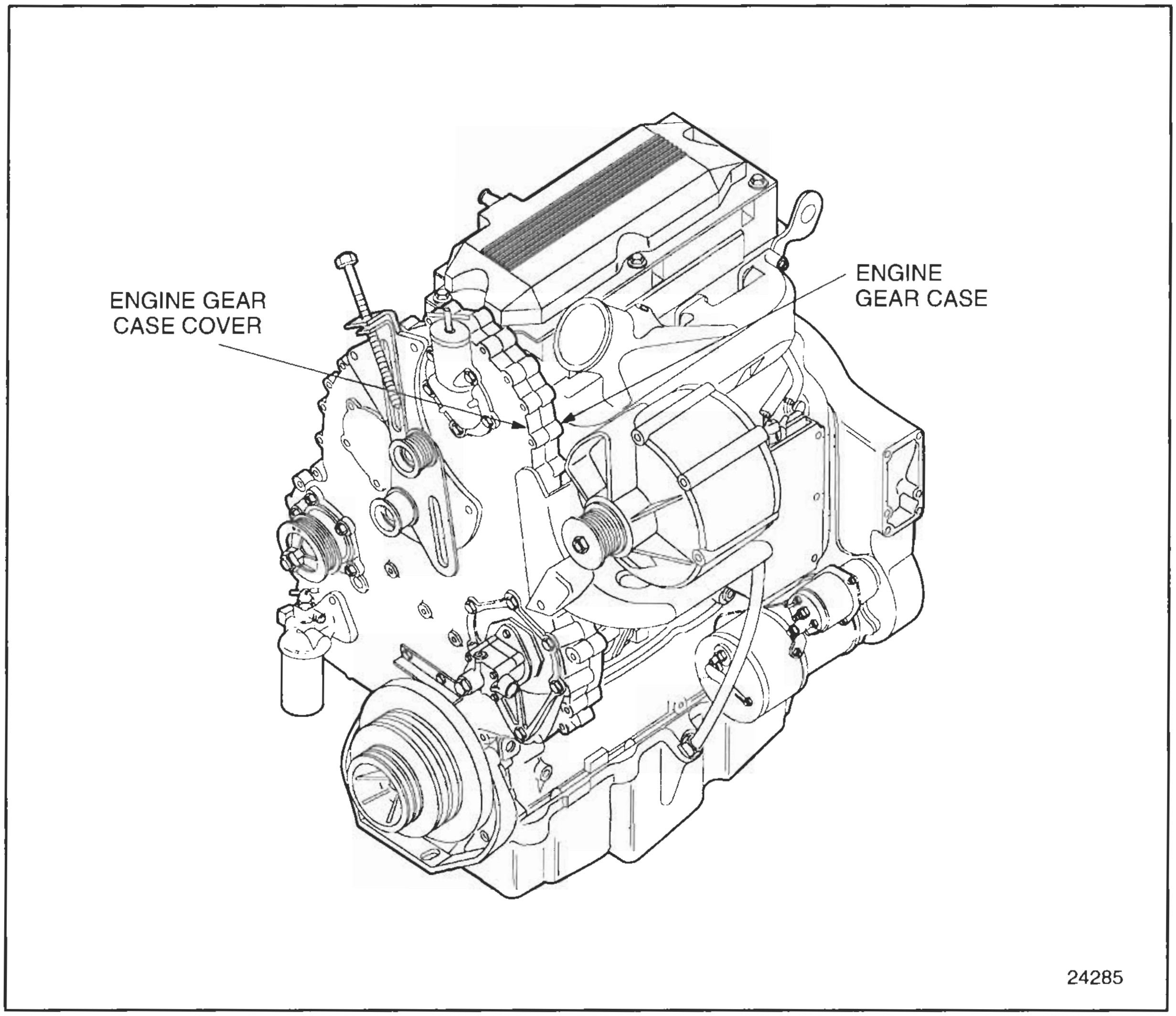
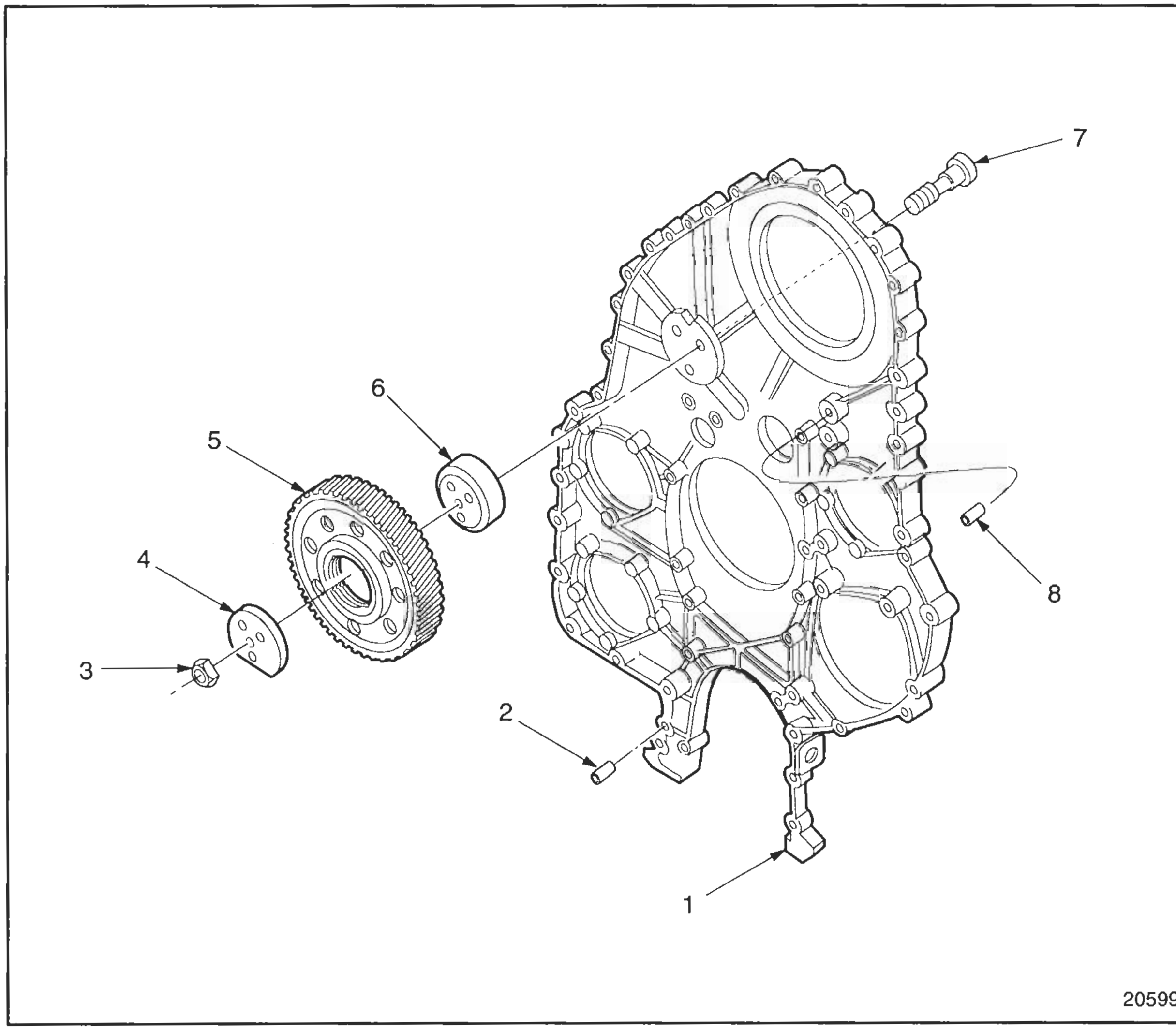


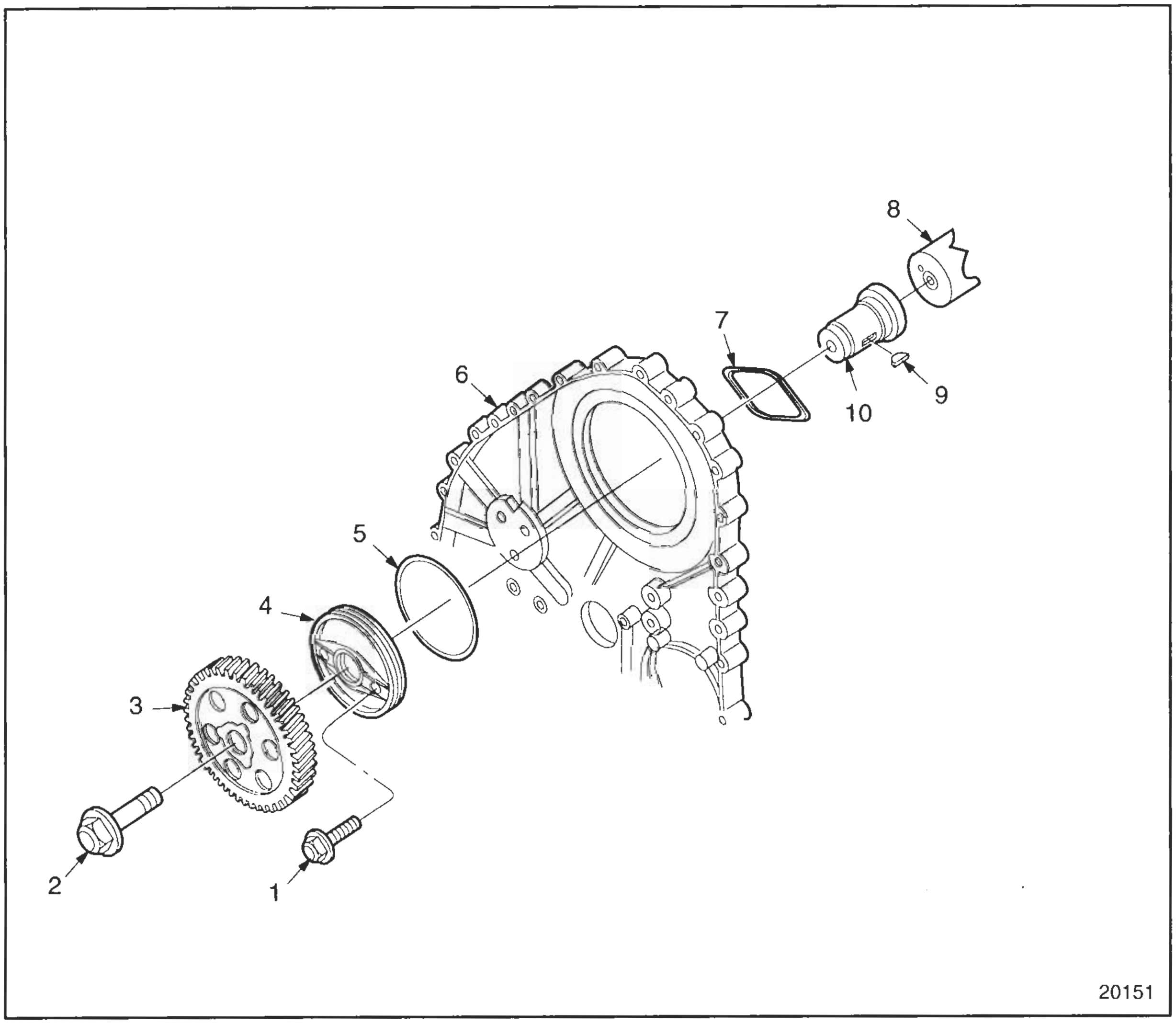
Figure 1–146 Gear Case and Related Parts

Several components are mounted to the gear case, including the adjustable idler gear assembly. See Figure 1–147. The camshaft drive gear assembly, see Figure 1–148, the air compressor drive assembly, see Figure 1–149, and the water pump assembly; see Figure 1–150.



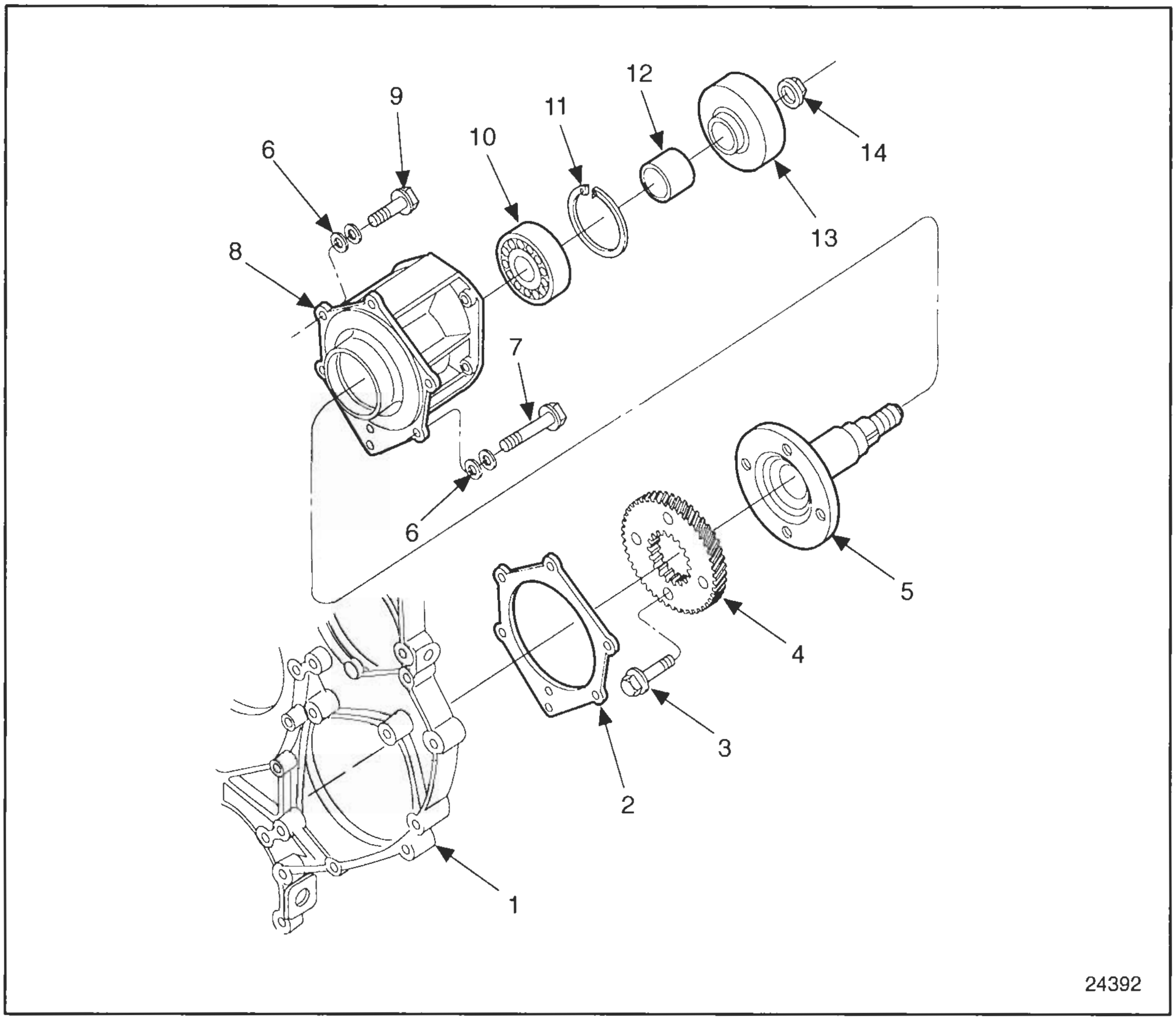
1. Gear Case Housing
2. Diamond Dowel
3. Adjustable Idler Gear Locknut (3)
4. Adjustable Idler Gear Hub Retaining Plate
5. Adjustable Idler Gear
6. Adjustable Idler Hub
7. Adjustable Idler Gear Stud (3)
8. Round Dowel

Figure 1–147 Adjustable Idler Gear Assembly



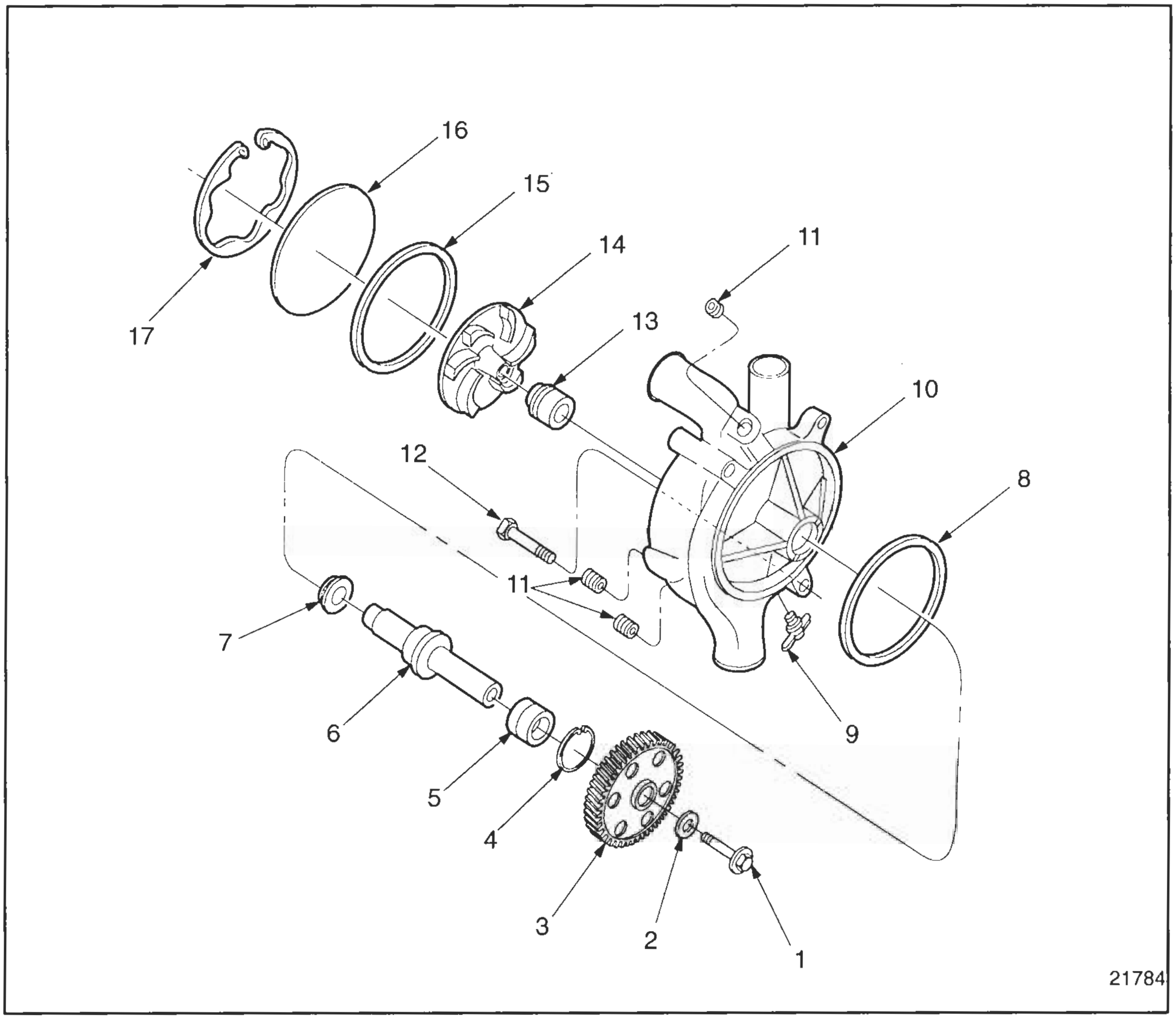
1. Bolt, Thrust Plate Retaining (2)
2. Bolt, Camshaft Hub Retaining
3. Drive Gear, Camshaft
4. Thrust Plate, Camshaft
5. O–ring
6. Gear Case
7. Seal, Thrust Plate
8. Camshaft
9. Key
10. Hub

Figure 1–148 Camshaft Drive Gear Assembly



1. Gear Case
2. Air Compressor Drive Gear Case Gasket
3. Air Compressor Drive Bolt
4. Air Compressor Drive Gear
5. Air Compressor Drive Shaft
6. Air Compressor Drive Housing
7. Washer
8. Air Comp. Drive Gear Case Short Bolt
9. Air Comp. Drive Gear Case Long Bolt
10. Air Compressor Drive Ball Bearing
11. Snap Ring
12. Spacer
13. Air Compressor Drive Hub
14. Air Compressor Drive Hub Flange Nut

Figure 1–149 Air Compressor Drive Assembly



1. Retaining Bolt
2. Washer
3. Water Pump Drive Gear
4. Snap Ring
5. Bearing Race Assembly
6. Drive Shaft
7. Oil Seal
8. Water Pump Housing O–ring
9. Drain Cock
10. Water Pump Housing
11. Pipe Plug
12. Water Pump Housing Retaining Bolt
13 Water Seal
14. Impeller
15. Water Pump Cover O–ring
16. Water Pump Cover
17. Water Pump Cover Snap Ring

Figure 1–150 Water Pump Assembly

To eliminate the possibility of oil leakage at the adjustable idler gear stud location, Detroit Diesel recommends the following:

When rebuilding a Series 50 Engines, **or** if the gear case is removed for any reason, the three original adjustable idler gear studs should be removed and replaced with new studs.

Before pressing studs into the gear case, coat the shanks and underside of the stud heads with **Loctite No. 242 Sealant**. This will prevent any oil leakage around the studs during engine operation.

The Timing Reference Sensor (TRS) is an electronic component that is bolted to the side of the gear case on the intake (left) side of the engine just above the oil pan. See Figure 1-151.

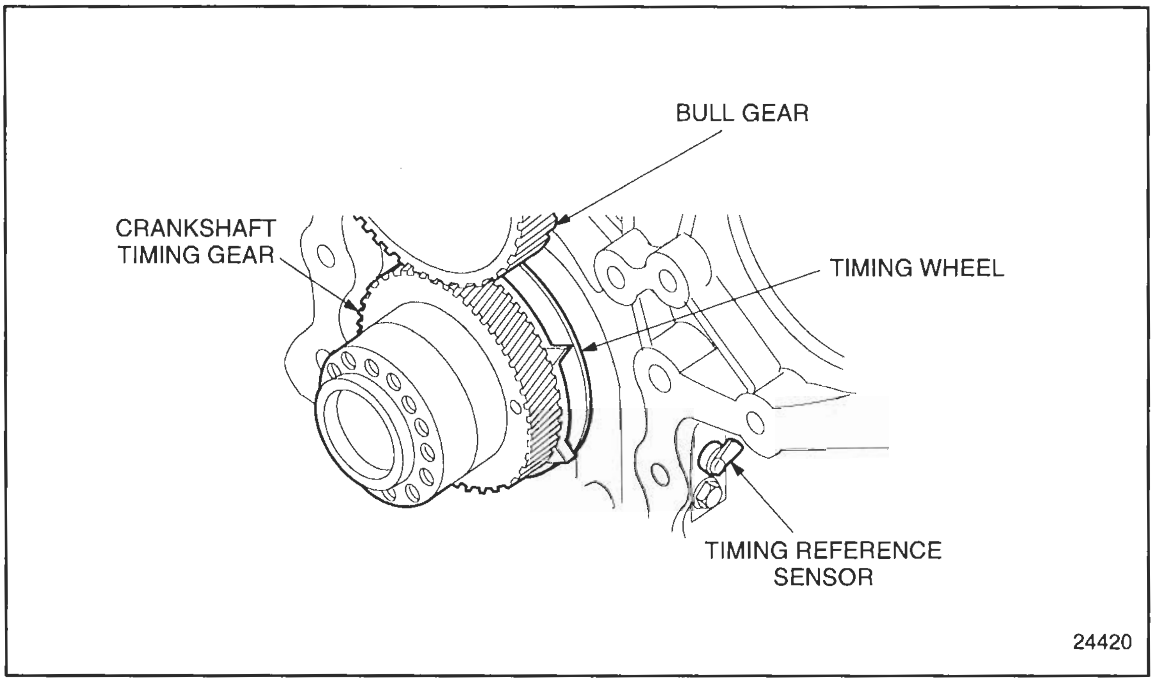


Figure 1–151 Timing Reference Sensor (TRS)

The Synchronous Reference Sensor (SRS) is an electronic component that is bolted to the gear case at the lower, intake (left) side of the engine. See Figure 1–152.

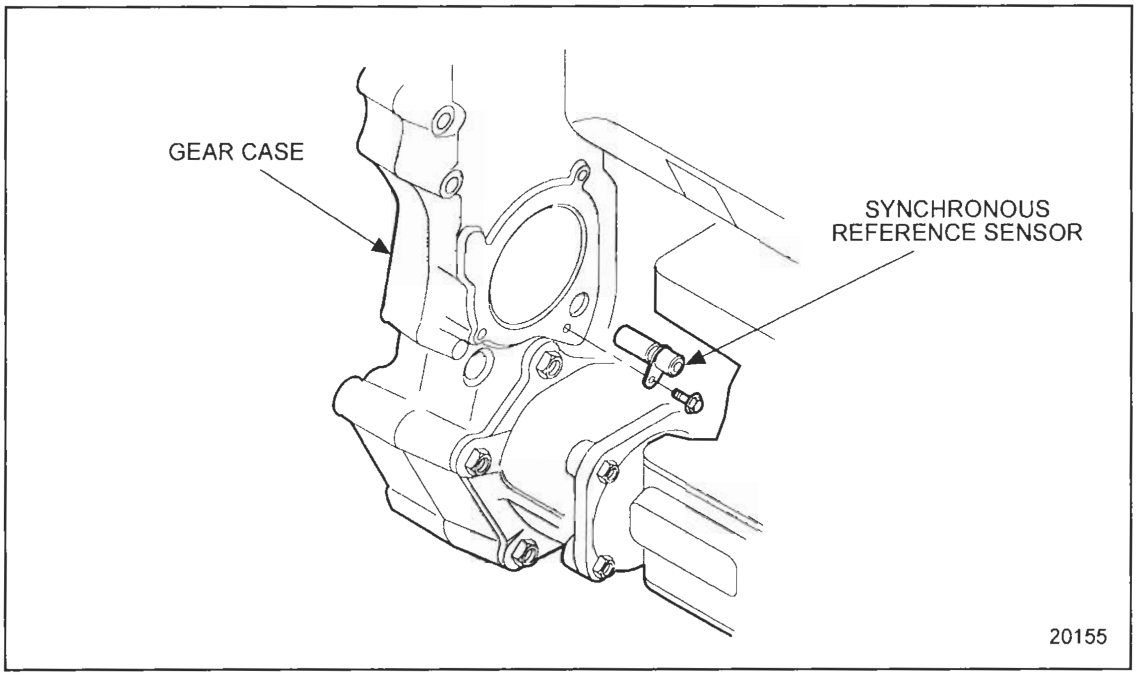


Figure 1–152 Synchronous Reference Sensor

An opening is provided in the center of the gear case, for the bull gear and camshaft idler gear assembly, which bolts directly to the engine block. See Figure 1–153.

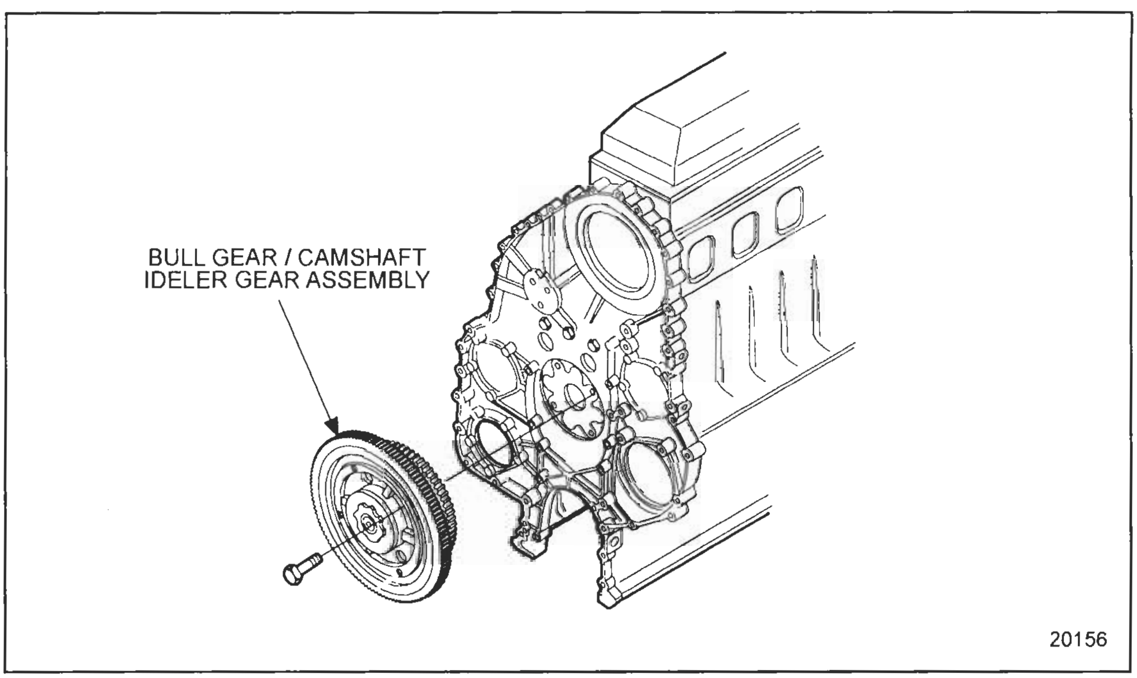


Figure 1–153 Bull Gear and Camshaft Idler Gear Assembly

An access cover is provided at the rear of the gear case on the cooler (right) side of the engine. This access cover provides an opening for inspection of the accessory drive assembly drive gear. See Figure 1-154.

NOTE:
This access cover opening may be cast closed on the rear of the gear case.

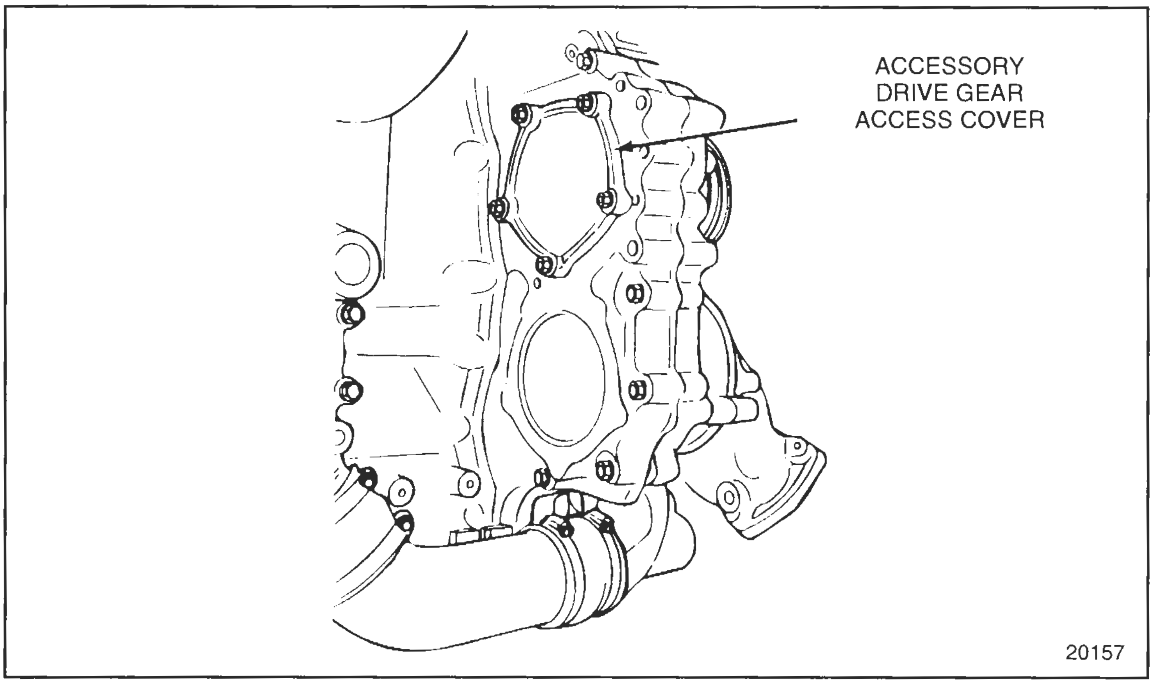


Figure 1–154 Accessory Drive Assembly Drive Gear Access Cover

Gear lash measurement and adjustment procedures for the gears in the engine gear train. Refer to section 1.21.2.1.

NOTE:
Do not use the oil plug location for oil supply or for checking oil pressure.

An oil gallery is drilled in the gear case casting, for lubrication of the adjustable idler gear assembly. A hole in the front of the cylinder block, indexes with the gear case gallery. At the edge of the gear case the gallery is threaded for insertion of a plug. An exit hole feeds the adjustable idler gear assembly. See Figure 1–155.

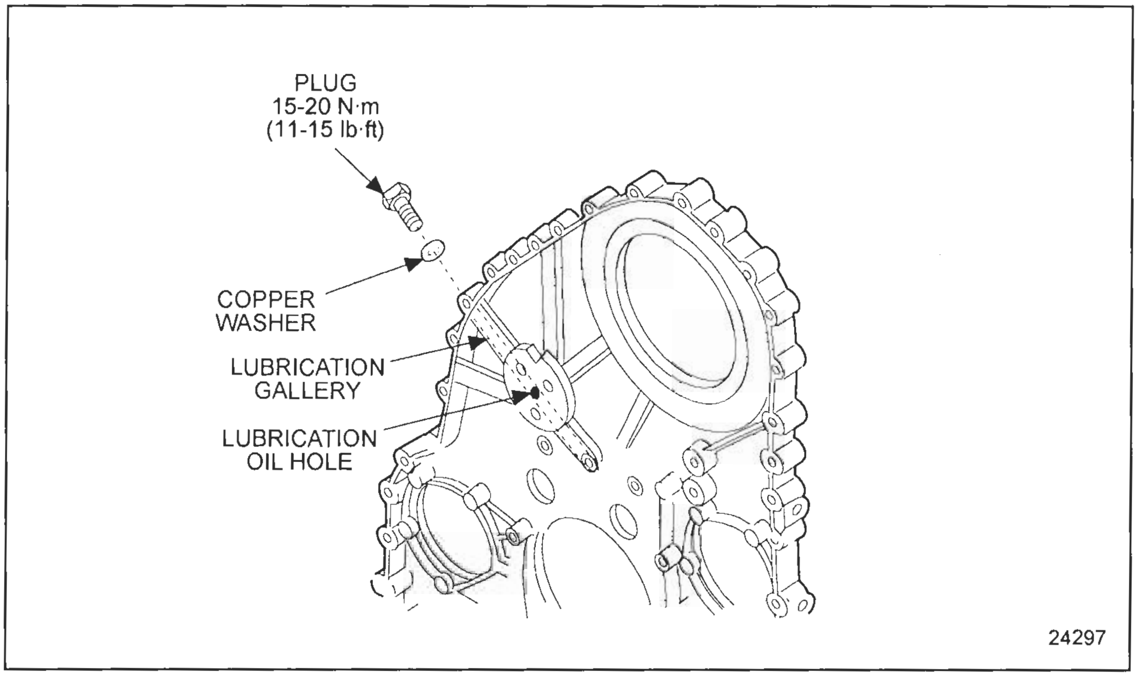


Figure 1–155 Adjustable Idler Gear Lubrication Gallery

1.11.1 Repair or Replacement of Gear Case

To determine if repair is possible or replacement is necessary perform the following procedure. See Figure 1–156.

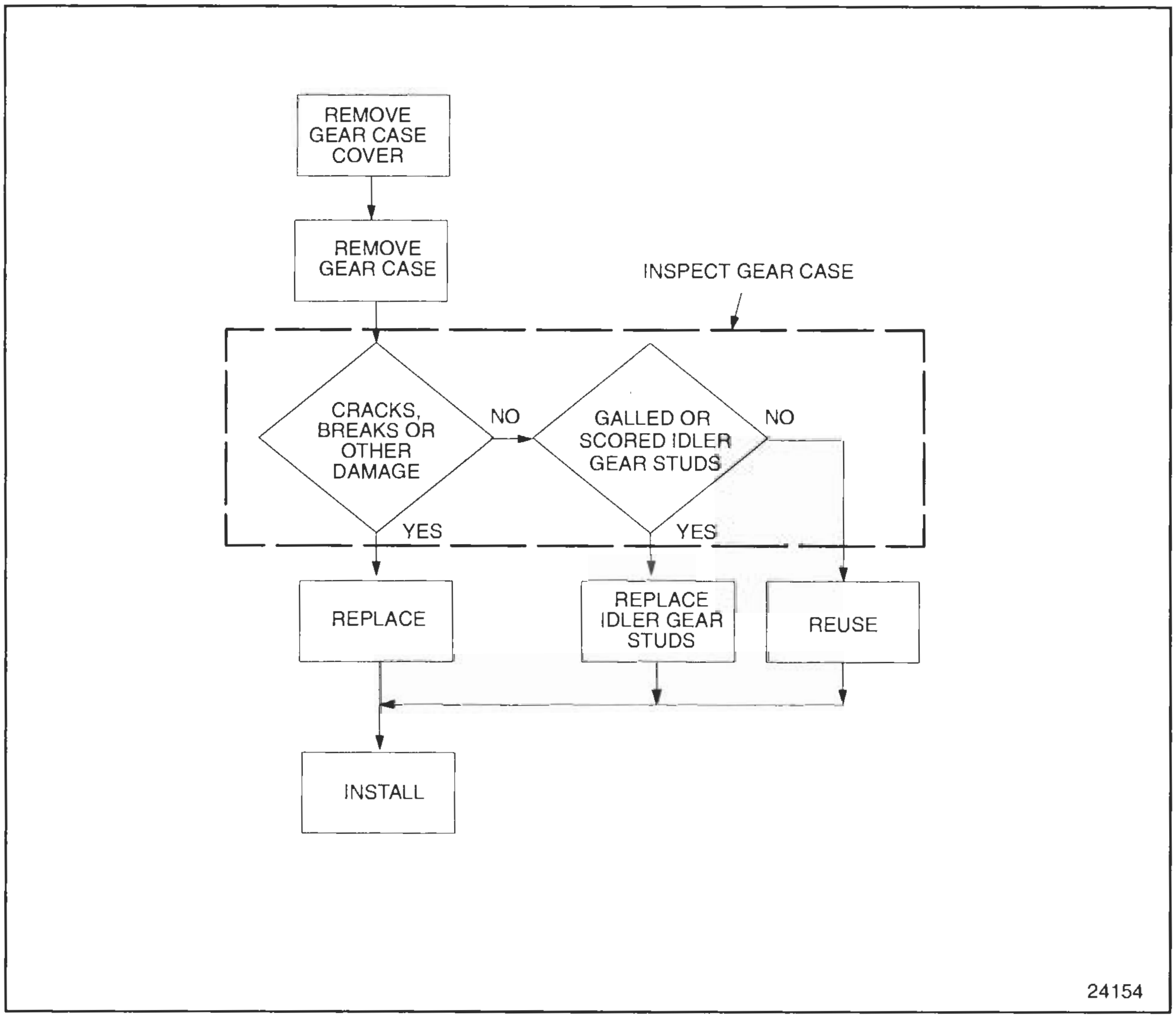


Figure 1–156 Flowchart for Repair or Replacement of Gear Case

1.11.2 Removal of Gear Case

To remove the gear case:

1. Remove the SRS. Refer to section 2.15.2.
2. Remove the TRS. from the gear case to prevent their damage on removal of the gear case. Refer to section 2.16.2.
3. Remove the rocker arm assemblies. Refer to section 1.3.2.
4. Perform all of the steps for camshaft removal; refer to section 1.22.2.
5. Remove the 3 bolts that secure the camshaft gear pilot tool, J 35906, to the gear case and remove the tool.
6. Refer to section 1.10.2, for case cover removal and perform the steps up to but not including, supporting the gear case cover with a suitable lifting device. For the final step, refer to step 14. See Figure 1–157.

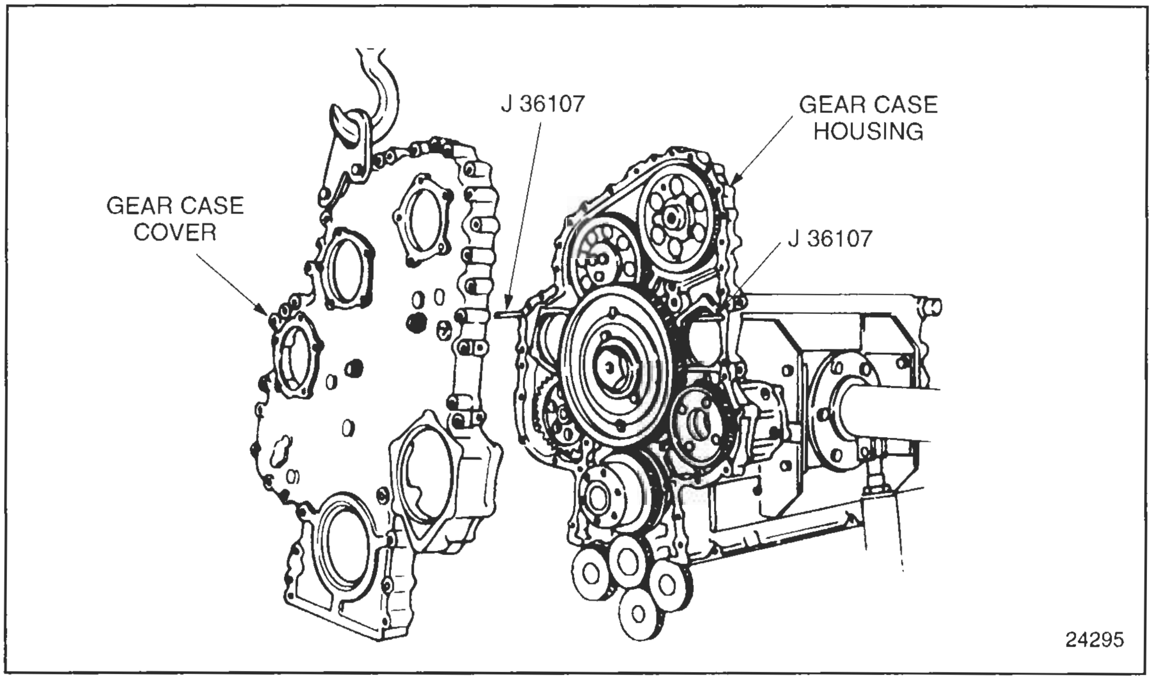


Figure 1–157 Gear Case Cover Removal

7. Remove the fuel pump from the fuel pump drive assembly (or air compressor). Refer to section 2.4.2.
8. Remove the air compressor. Refer to section 10.1.2.
9. Remove the air compressor drive assembly. Refer to section 10.2.2.

10. Install the crankshaft protector, J 35994, to the oil seal contact area of the crankshaft. This will help to protect the crankshaft seal surface when removing the bull gear and camshaft idler gear assembly. See Figure 1–158.

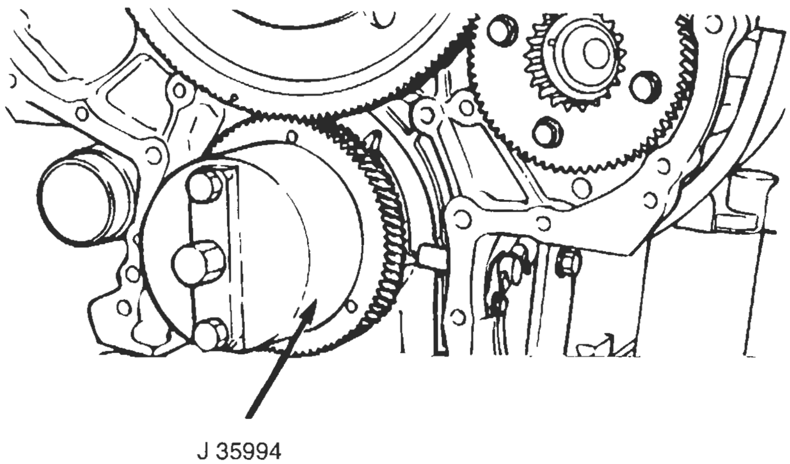


Figure 1–158 Crankshaft Protector Installation

11. Remove the bull gear and camshaft idler gear assembly from the engine. Refer to section 1.25.2.
12. Remove the adjustable idler gear assembly from the gear case. Refer to section 1.24.2.
13. Using a plastic hammer or fiber mallet, tap the rear face of the camshaft thrust plate to remove the thrust plate, camshaft drive gear hub and camshaft drive gear from the gear case.

14. Remove the 12 bolts that secure the gear case to the engine block. See Figure 1–159. Also remove the bolt that secures the gear case stabilizer bracket to the gear case.

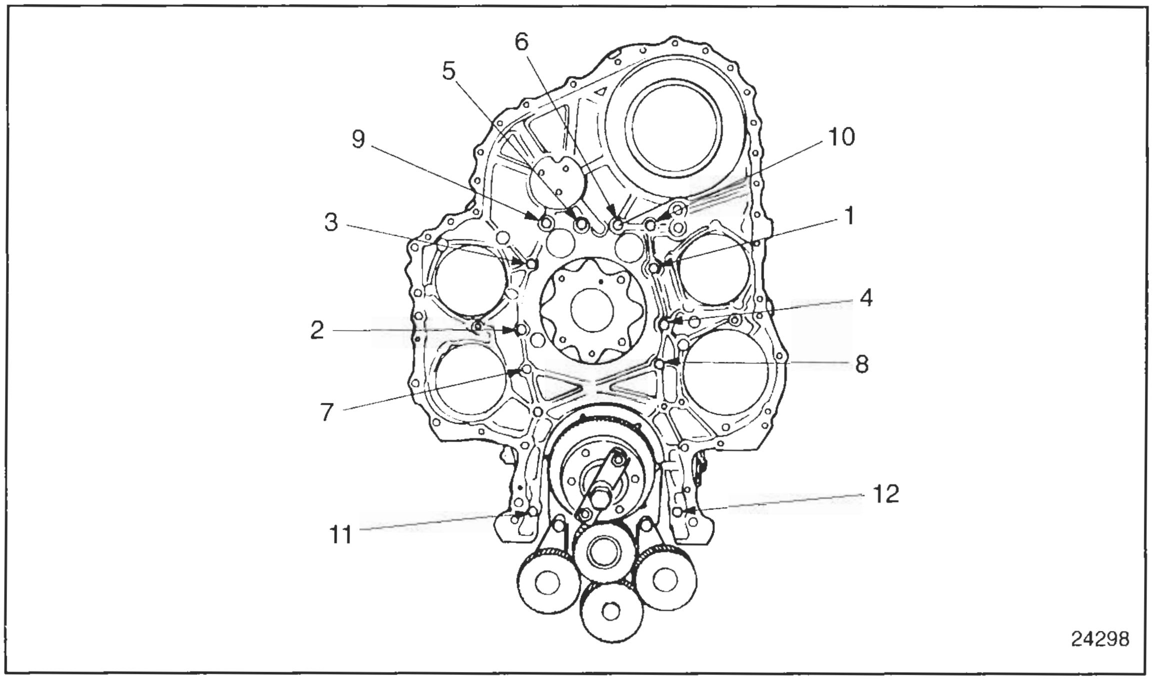


Figure 1–159 Gear Case Mounting Bolt Locations

15. Using a leather or cloth–wrapped strap, support the gear case. See Figure 1–160.

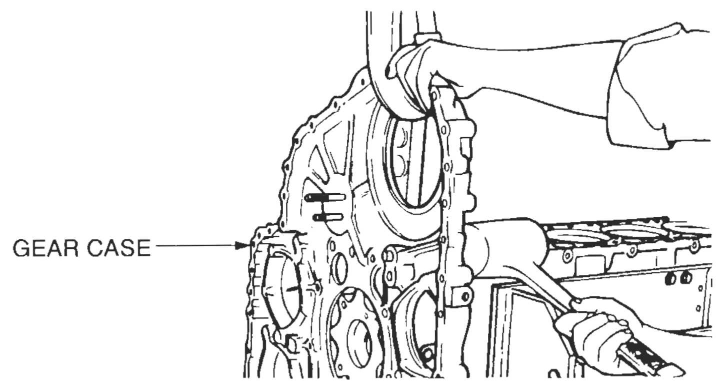


Figure 1–160 Gear Case Removal

16. Use a rubber hammer or plastic mallet to loosen the gear case from the cylinder block dowels.

1.11.2.1 Inspection of Gear Case

Clean all of the old gasket sealer from the mating surfaces of the gear case, gear case cover and engine block. Refer to "Gasket Eliminator Removal" in the "General Information" section at the beginning of this manual. Clean the gasket material from the mating surfaces of any components or access covers that were removed from the gear case cover or gear case.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

Clean all of the parts with clean fuel oil and dry with compressed air. Remove the oil gallery plug at the edge of the gear case. See Figure 1–155. Use compressed air to ensure the oil gallery is completely free of blockage. If necessary, use a wire brush to clean the gear case oil gallery.

Inspect the gear case for stress cracks, breaks, or other damage. Repair or replace as necessary. Inspect the adjustable idler gear studs for signs of galling or scoring. Replace as necessary. Inspect all the individual components as outlined under the appropriate section.

1.11.3 Installation of Gear Case

Use the following instructions for gear case installation:

NOTE:
The installation of Gasket Eliminator to the gear case–to–block mating surfaces at the top of the block is critical. Excess gasket eliminator material can extrude into the oil passage between the block and gear case, causing early failure of components. In addition, the bull gear recess area MUST be cleaned of any and all foreign material after installation of the gear case to the engine block.

1. Apply a thin film of gasket eliminator PT–7276 (Loctite 51580) or equivalent to the cylinder block. See Figure 1–161. Carefully smooth the bead around the block–to–gear case oil passage to avoid contamination.

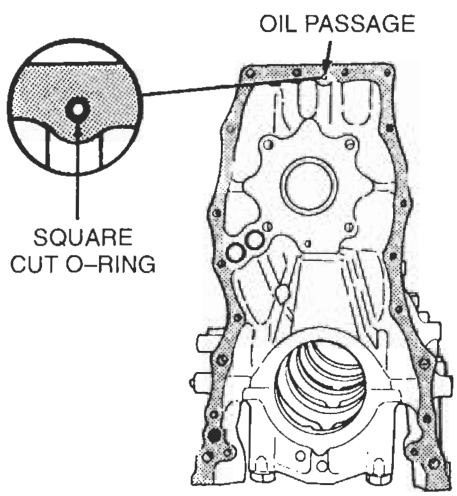


Figure 1–161 Gasket Eliminator Application

2. Insert Gear Case Alignment Plug, J 35651, into the bull gear and camshaft idler gear hub recess in the cylinder block. See Figure 1–162.

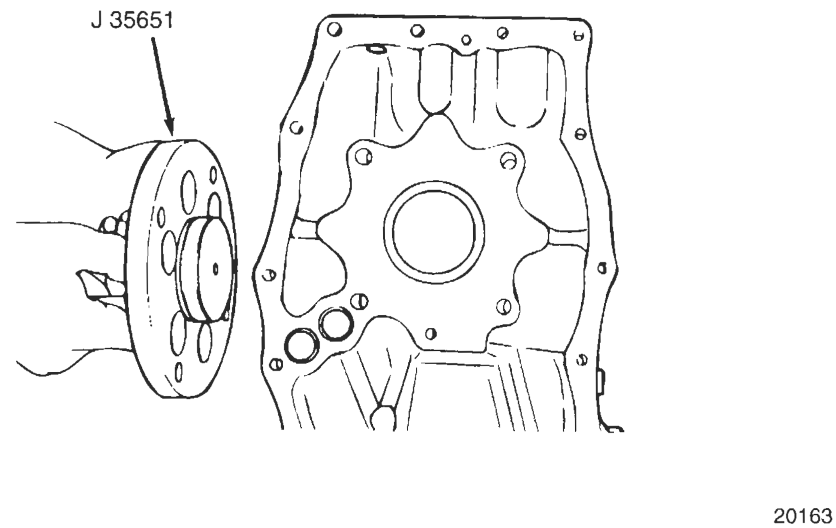


Figure 1–162 Gear Case Alignment Plug

3. Using a suitable lifting sling made of cloth or leather, position the bull gear and camshaft idler gear opening of the gear case over the gear case alignment plug. Index the hole in the gear case mating surface with the diamond dowel at the lower left corner of the cylinder block. See Figure 1-163.

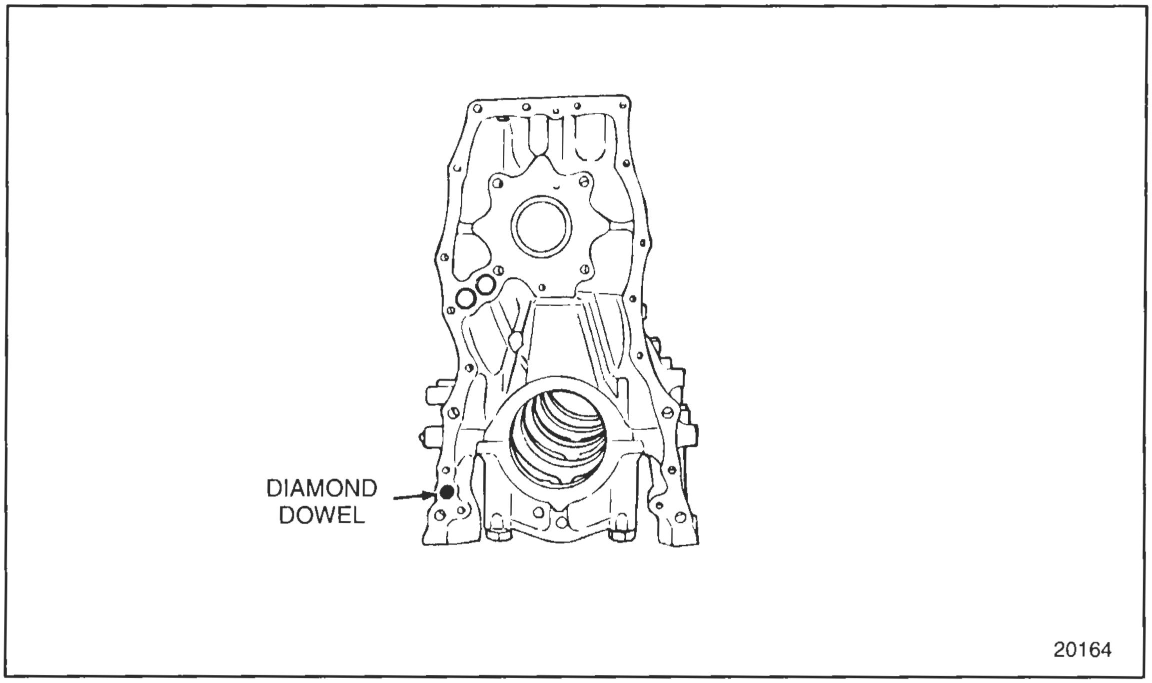


Figure 1–163 Cylinder Block Locating Dowel

4. With the gear case alignment plug fully seated, the gear case centered on the alignment plug and the diamond dowel in the cylinder block indexed with its mating hole in the gear case, the gear case is positioned properly for bolt installation. See Figure 1-164.

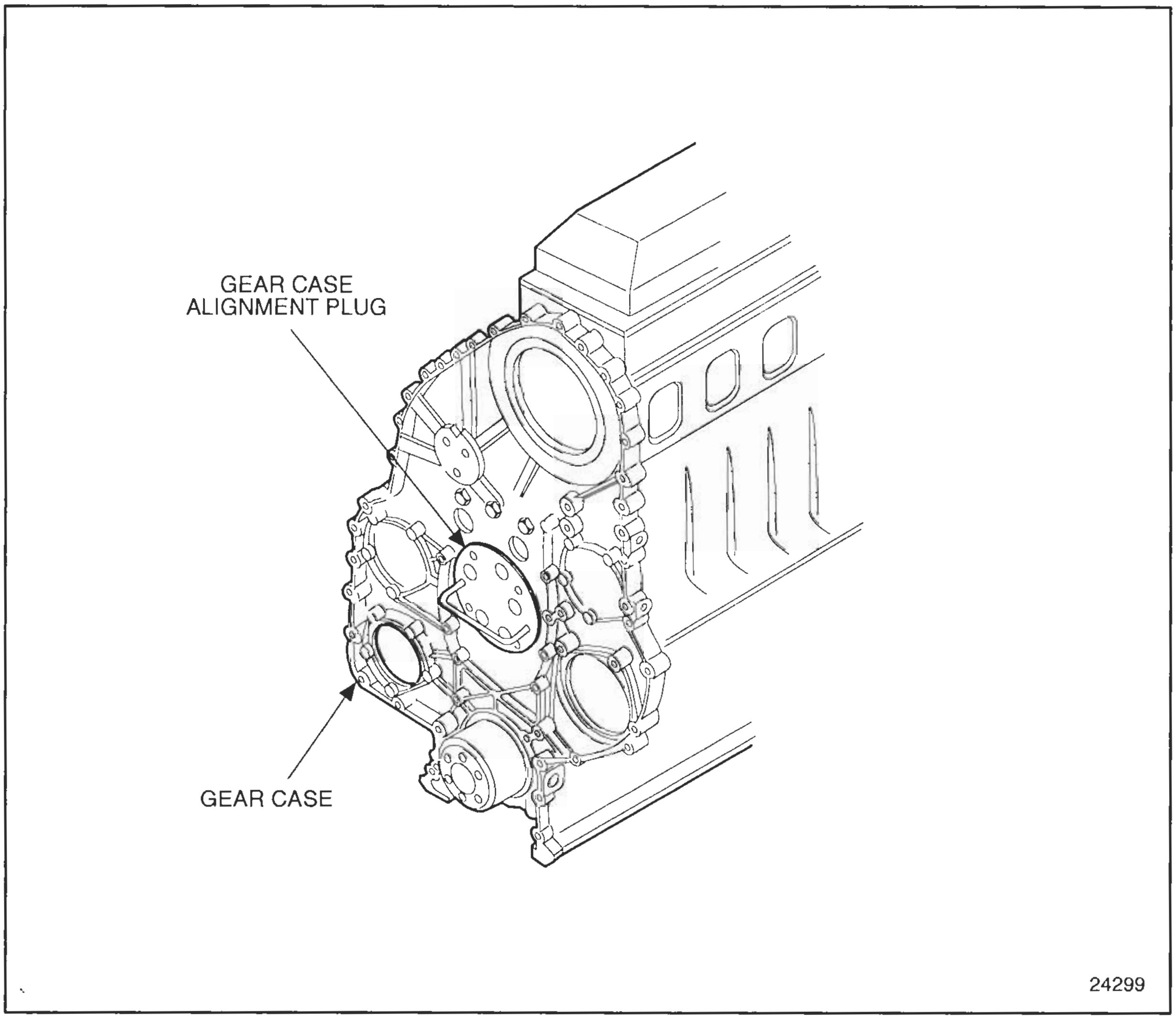


Figure 1–164 Gear Case Positioning

NOTE:
Gasket Eliminator cures with the absence of air. The time between the installation of the gear case, and torquing of the bolts that secure the gear case to the cylinder block should be kept to a minimum.

5. Install the 12 gear case-to-cylinder block retaining bolts, finger tight.

6. See Figure 1–165, and tighten the gear case–to–cylinder block bolts to 58–73 N·m (43–54 lb·ft) using the sequence shown.

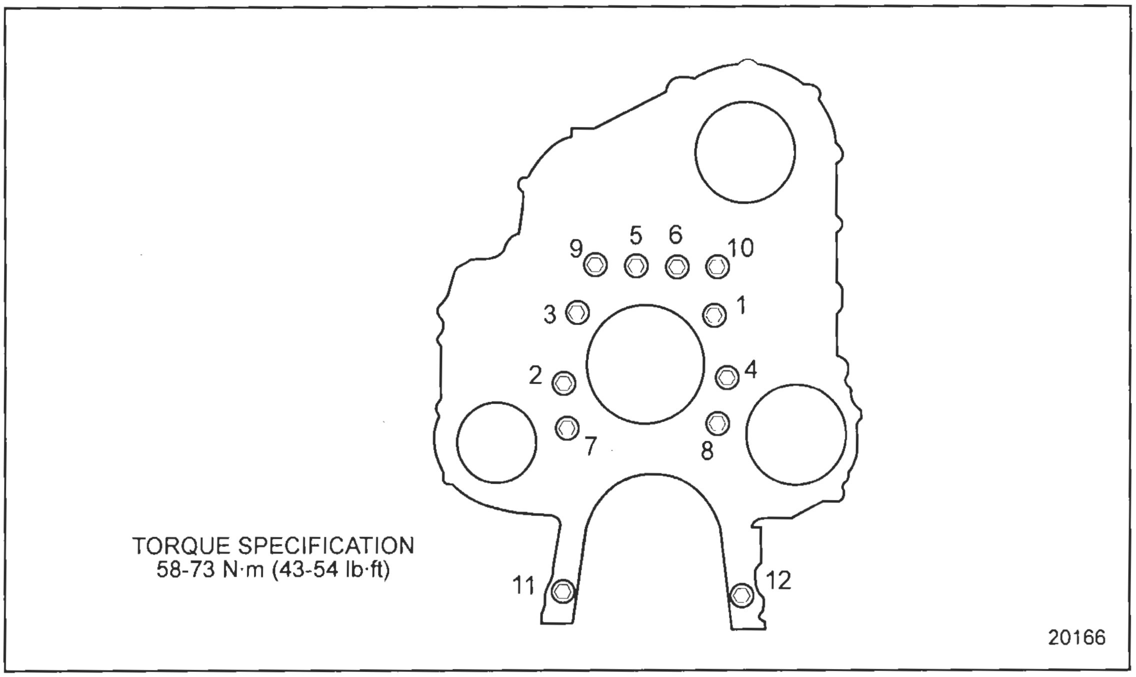


Figure 1–165 Gear Case Bolt Torque Sequence

7. Remove the gear case alignment plug from the gear case.
8. Install the air compressor. Refer to section 10.1.4.
9. Install the air compressor drive assembly. Refer to section 10.2.4.

10. Install the fuel pump to gear case. Refer to section 2.4.5.
11. Refer to section 4.2.7 and install the water pump assembly.
12. Lubricate the rubber O-ring on the camshaft thrust plate with clean engine oil. Install the camshaft thrust plate assembly, with the camshaft drive gear and hub in place to the gear case, using a plastic hammer or fiber mallet to tap the thrust plate rearward in the gear case just enough to start it in the gear case. See Figure 1–166.

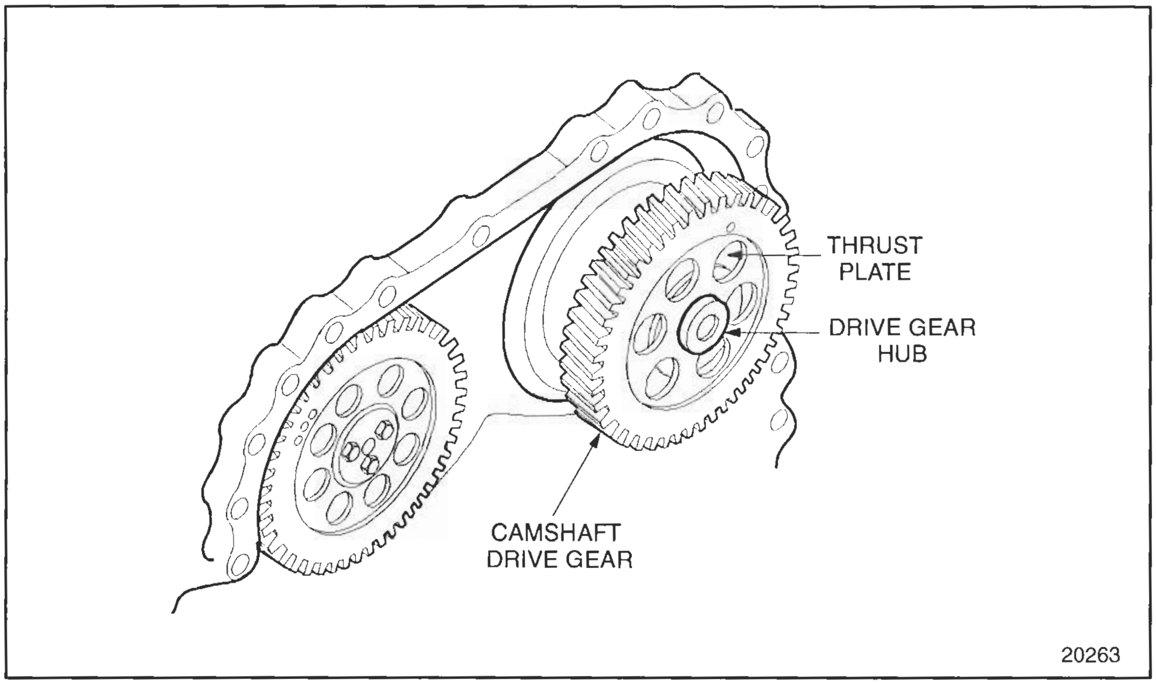
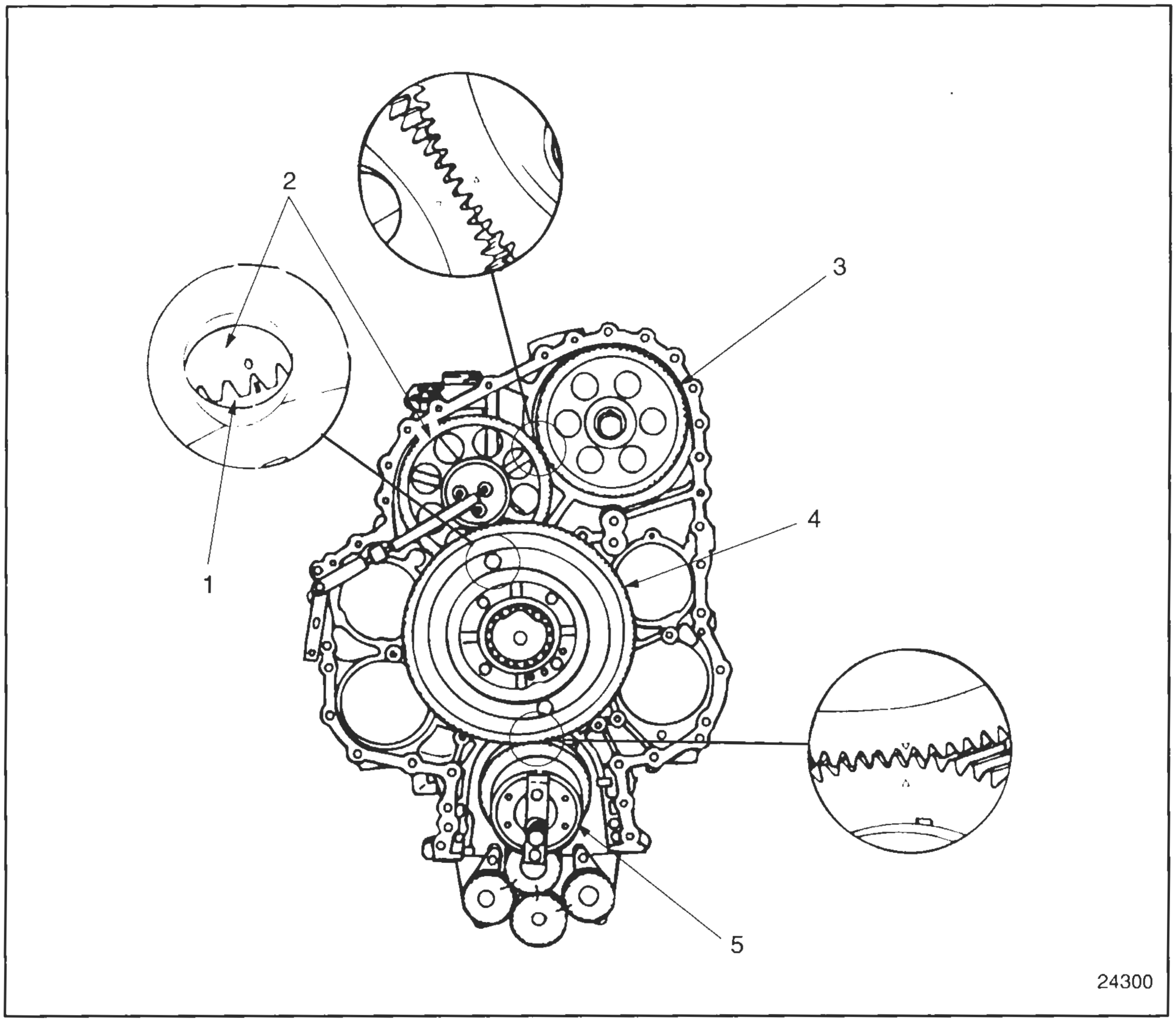


Figure 1–166 Camshaft Thrust Plate Installation

13. Install the adjustable idler gear assembly to the gear case. Refer to section 1.24.3. Align the timing marks of the adjustable idler gear and camshaft drive gear. See Figure 1-167.



1. Camshaft Idler Gear
2. Adjustable Idler Gear
3. Camshaft Drive Gear
4. Bull Gear
5. Crankshaft Timing Gear

Figure 1-167 Engine Gear Train Timing Marks

14. Inspect the bull gear and camshaft idler gear access opening in the gear case and remove any foreign material.

15. Install two bull gear guide studs, J 35785 to the cylinder block. See Figure 1–168.

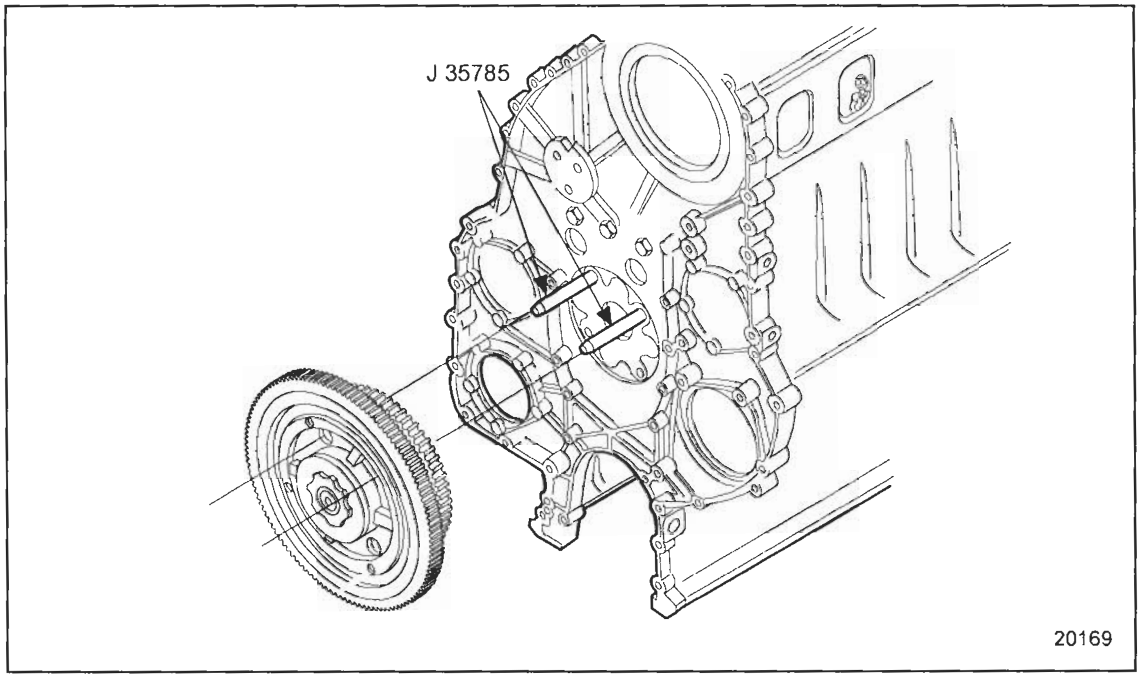


Figure 1–168 Bull Gear Guide Stud Installation

16. Install the crankshaft protector, J 35994 to the oil seal contact area of the crankshaft. This will help to protect the crankshaft seal surface when installing the bull gear and camshaft idler gear assembly.

NOTICE:
Always install crankshaft protector when installing the bull gear and camshaft idler gear assembly to prevent damaging the crankshaft oil seal contact surface.

17. Install the bull gear and camshaft idler gear assembly to the guide studs. Align the timing marks on the bull gear and the crankshaft timing gear and the camshaft idler gear and adjustable idler gear; see Figure 1–167, and slide the bull gear and camshaft idler gear assembly forward to seat it in the recess in the gear case and cylinder block.

18. Working through the lightening holes in the bull gear, install two of the bull gear assembly mounting bolts through the hub and into the cylinder block. Tighten the bolts finger tight.
19. Remove the two bull gear guide studs. Install the remaining two bull gear assembly mounting bolts. Tighten the bolts to 101–126 N·m (75–93 lb·ft) torque. Tighten in a clockwise sequence.
20. Check the timing marks on the gears to ensure the gear train is properly timed. See Figure 1–167.
21. Perform the following:
    [a] Crankshaft timing gear–to–oil pump idler gear lash measurement. Refer to section 1.21.2.1 step 2.
    [b] Crankshaft timing gear–to bull gear lash measurement. Refer to section 1.21.2.1 step 3.
    [c] Refer to section 1.10.3 for gear case cover installation.
22. Refer to section 1.22.5, "Installation of Camshaft and Camshaft Bearings" and perform the necessary steps.
23. Refer to section 1.21.2.1 for bull gear–to–accessory pulley drive gear lash measurement and perform step 10.
24. If the stabilizer bracket has not been removed, loosen the two bolts securing the bracket to the cylinder head. Install the gear case stabilizer bracket–to–gear case bolt and tighten to 58–73 N·m (43–54 lb·ft) torque. Then, retighten the stabilizer bracket–to–cylinder head bolts to 58–73 N·m (43–54 lb·ft) torque.
25. Continue engine assembly.

1.12 CRANKSHAFT VIBRATION DAMPER

A viscous type vibration damper is mounted on the front end of the crankshaft to reduce torsional vibrations to a safe value. See Figure 1-169.

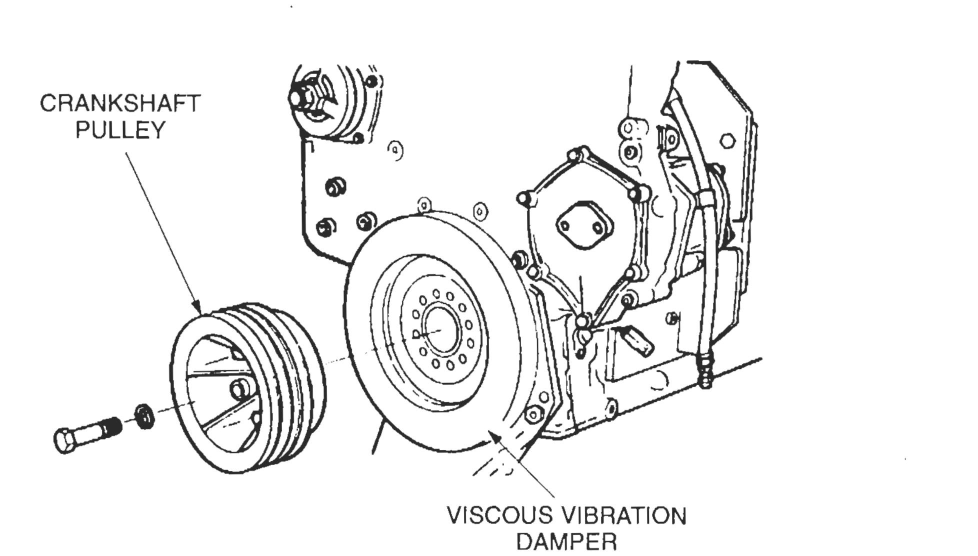


Figure 1–169 Viscous Vibration Damper Mounting

The viscous damper assembly consists of a sealed outer shell, an internal flywheel and a quantity of highly viscous fluid. See Figure 1-170.

A vibration damper safety shield is recommended in industrial and marine applications in which the engine operates without a hood or other protective covering in an open or unprotected area.

A properly designed and installed safety shield protects the damper from damage, prevents direct physical contact with the damper during engine operation, and significantly reduces the potential for damper-related personal injury.

Detroit Diesel Corporation does not manufacture, sell or install vibration damper safety shields due to the wide variety of installations in which Detroit Diesel engines are applied. Space restrictions in these numerous applications make it necessary to design an appropriate type of shield for each installation.

The responsibility for designing and installing properly shaped and constructed safety shields, therefore, rests with the OEM (Original Equipment Manufacturer), distributor, or other fabricator designing or and/or manufacturing products in which they apply Detroit Diesel engines.

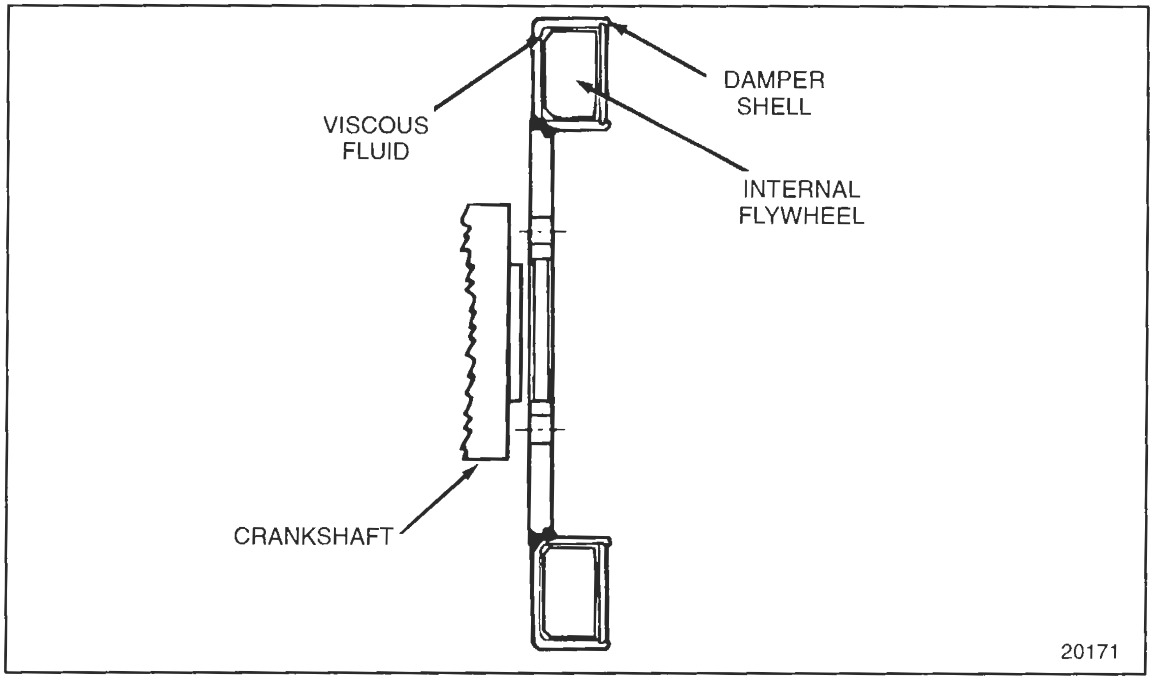


Figure 1–170 Viscous Vibration Damper Detail

During operation, the outer shell, which is firmly attached to the crankshaft, turns at the same speed as the crankshaft, its motion being transferred to the flywheel through the fluid within the shell. Since "fluid-drive" is more or less inefficient with frequent speed changes, considerable flywheel slippage will take place as the power impulses are transmitted through the crankshaft. In this type of operation, the slippage is desirable since the acceleration and deceleration of the flywheel in the damper lessens the vibration amplitude, reducing its effects to a level harmless to the engine.

1.12.1 Repair or Replacement of Crankshaft Vibration Damper

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-171.

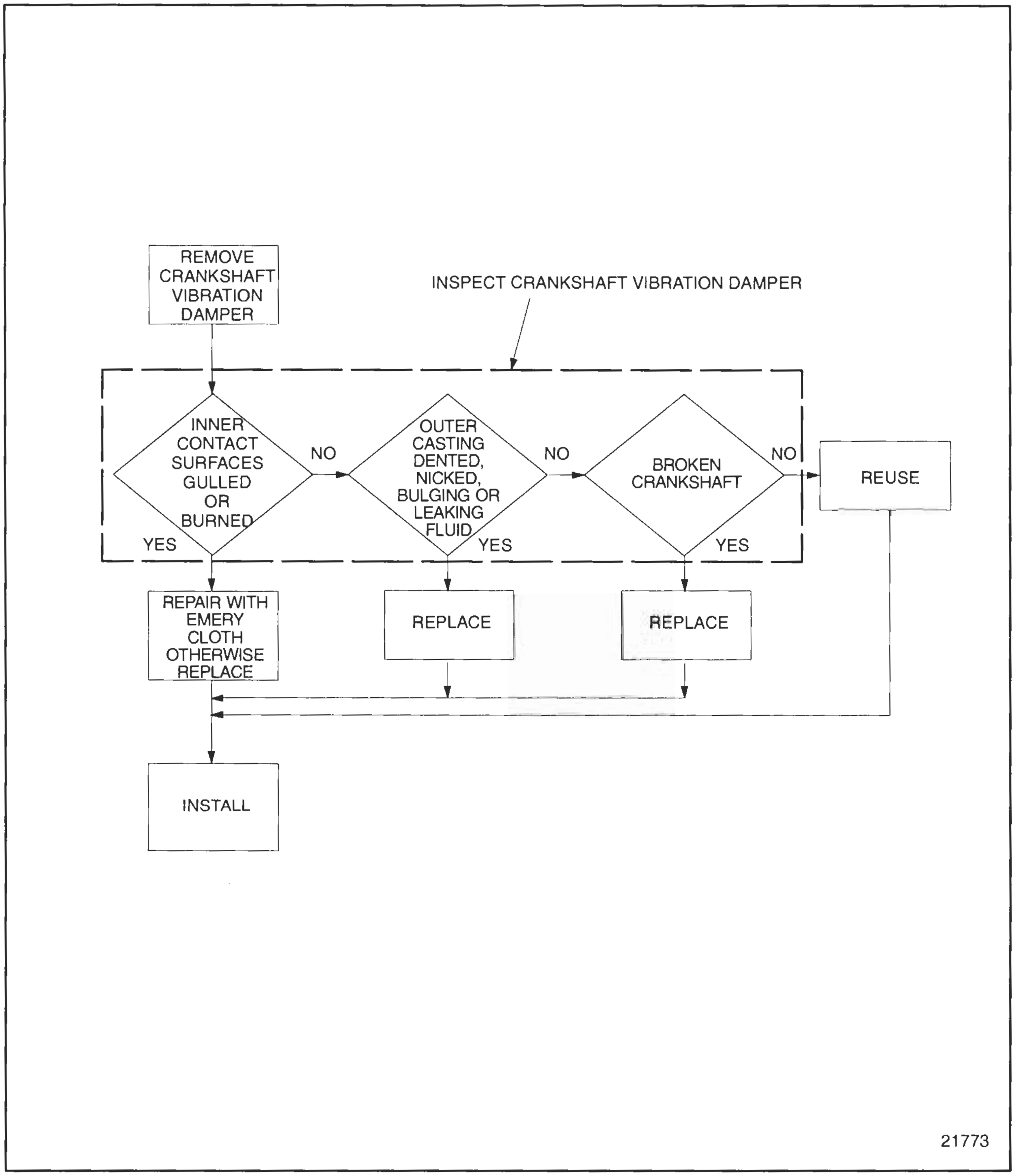


Figure 1-171 Flowchart for Repair or Replacement of Crankshaft Damper

1.12.2 Cleaning and Removal of Crankshaft Vibration Damper

Precleaning is not necessary.

CAUTION:

Personal injury and/or engine damage may result from direct physical contact with the vibration damper of an operating engine. Damper damage, engine damage, or both may occur if tools or other objects strike or become lodged behind the damper during operation. Objects coming in contact with the damper of an operating engine also may be thrown off by the damper with force, becoming a dangerous projectile which could cause personal injury, property damage, or both.

Remove crankshaft vibration damper as follows:

1. Remove the drive belts from the crankshaft pulley.
2. Remove the inspection plug in the bottom of the flywheel housing and install the flywheel lock, J 36375. See Figure 1–172.

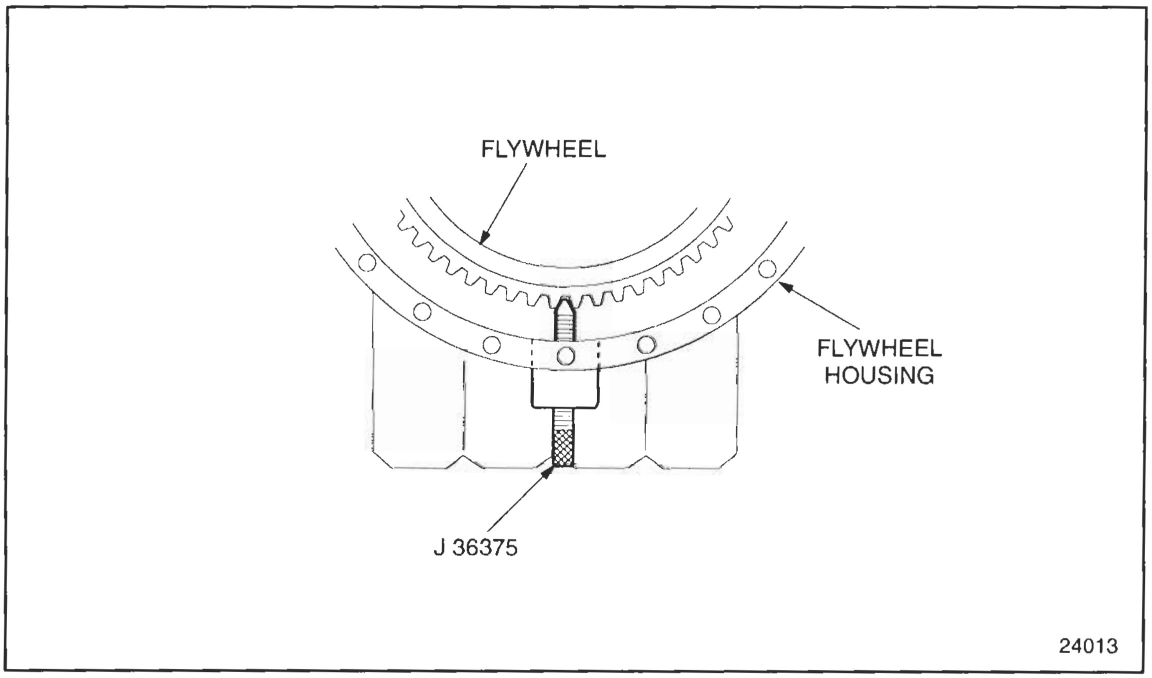


Figure 1–172 Flywheel Lock

3. Thread the center screw of the tool in until the tip of the tool rests between two teeth of the flywheel ring gear.

NOTE:
It may be necessary to bar the engine over (using the square hole in the middle of the crankshaft pulley) so that the tool center screw is exactly between two teeth.

4. Tighten the knurled knob finger tight.
5. Remove two of the six crankshaft pulley–to–crankshaft attaching bolts and hardened washers that are 180° apart.
6. Install two guide studs, J 36235 into the holes that the bolts were removed from.

NOTICE:
Use care when removing the crankshaft pulley as the vibration damper may come off. If the damper is allowed to fall, internal damage to the damper may result.

7. Remove the remaining four crankshaft pulley bolts and hardened washers.

NOTICE:
Do not pound with a hammer or pry with other tools to remove the viscous damper from the crankshaft, since the outer shell may be dented and cause the flywheel to turn at the same speed as the outer shell. This renders the damper ineffective. The damper CANNOT be repaired.

8. Remove the vibration damper by sliding it off the guide studs.
9. Remove the flywheel lock and guide studs.

1.12.2.1 Inspection of the Vibration Damper

Inspect the vibration damper as follows:

NOTICE:
Dents may render the damper ineffective.

1. Inspect the outer casing of the damper for damage.
   [a] Check outer casing for dents, nicks, fluid leaks or bulges.
   [b] If any dents are detected, replace with new damper.
   [c] Bulges or splits indicate that the damper fluid has deteriorated. If any are detected, replace with new damper.
2. Inspect the damper inner contact surfaces and the crankshaft end for damage. See Figure 1–173
   [a] Check for galling or burrs.
   [b] Slight scratches or burrs may be removed with an emery cloth.
   [c] If deep scratches are detected, replace with new damper.

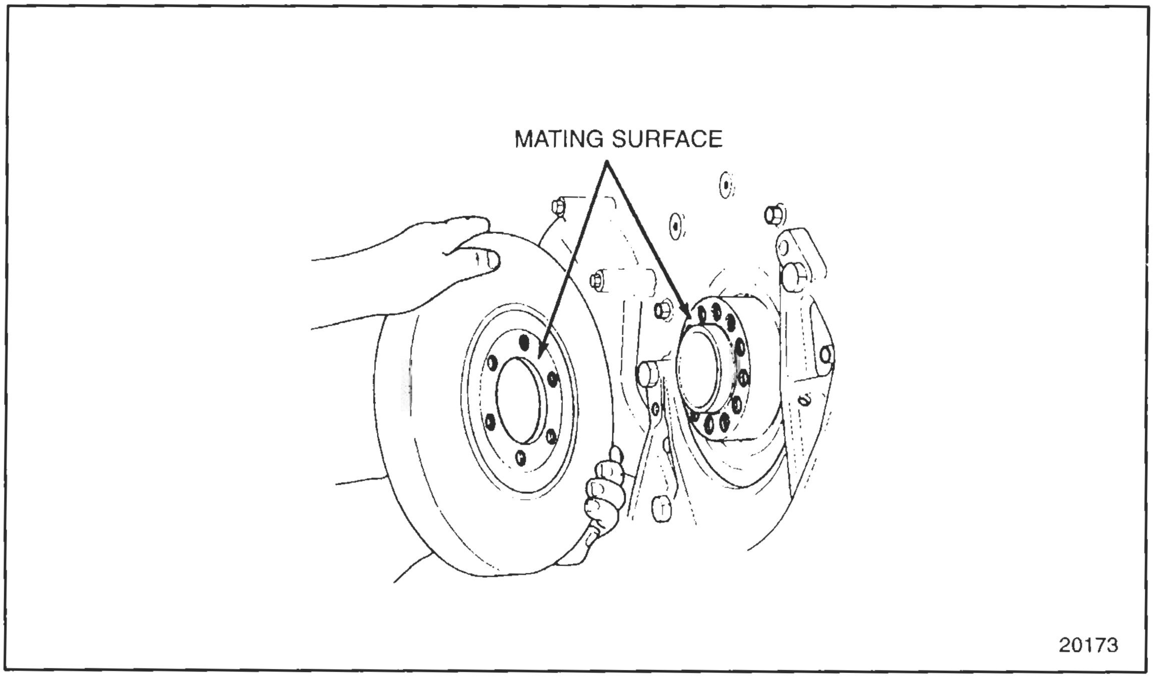


Figure 1–173 Damper and Crankshaft Contact Surfaces

3. Regardless of its condition, a viscous type damper must be replaced at normal engine overhaul or whenever the engine has experienced crankshaft breakage.
4. If the vibration damper has been damaged, inspect the crankshaft. Refer to section 1.7. Crankshaft damage may have resulted.

NOTICE:
A loose engine mount could lead to damage of the vibration damper by allowing the engine to move slightly during operation.

5. Inspect the engine mounts to be sure they are not loose, cracked or deteriorated.

1.12.3 Installation of Crankshaft Vibration Damper

Install the crankshaft vibration damper as follows:

1. Install the flywheel lock, J 36375, to the inspection plug hole in the bottom of the flywheel housing. See Figure 1-172.

NOTE:
It may necessary to bar the engine over (using barring Tool J 36237) so that the tool center screw is exactly between two teeth.

2. Thread the center screw of the tool in until the tip of the tool rests between two teeth of the flywheel ring gear. Tighten the knurled knob finger tight.
3. Install two guide studs, J 36235, to two of the holes in the crankshaft pulley 180° apart. A light coating of an anti-seize compound should be applied to the pilot diameter (not the face of the crankshaft) to reduce future removal difficulty.
4. Install the vibration damper to the end of the crankshaft. The six holes in the damper are equally spaced, and the damper may be installed in any position. The part No. on the face of the damper should face out, away from the engine.
5. Install the crankshaft pulley to the crankshaft. The crankshaft pulley may be installed in any position.
6. Install four of the bolts, with hardened washers installed, through the pulley and damper and into the crankshaft. Tighten the bolts finger tight.
7. Remove the two guide studs.
8. Install the remaining two pulley bolts with hardened washers installed.
9. Tighten the six bolts to 182-210 N·m (134-155 lb·ft) torque. Proceed in a clockwise direction until all bolts are torqued.
10. Remove the flywheel lock tool.
11. Install the pipe plug to the inspection hole in the flywheel housing.
12. Install the drive belts to the crankshaft pulley. Adjust the belt tensions to the specifications. Refer to section 13.5.7.
13. Install any other components that were removed for this operation.
14. Refer to section 11.6 for verification of proper crankshaft vibration damper installation.

1.13 CRANKSHAFT PULLEY

The crankshaft pulley is secured to the end of the crankshaft with six special bolts and hardened washers. The vibration damper is clamped between the crankshaft pulley and crankshaft. See Figure 1-174.

NOTE:
Do not substitute any other bolts or washers. The crankshaft pulley bolts and washers are special parts.

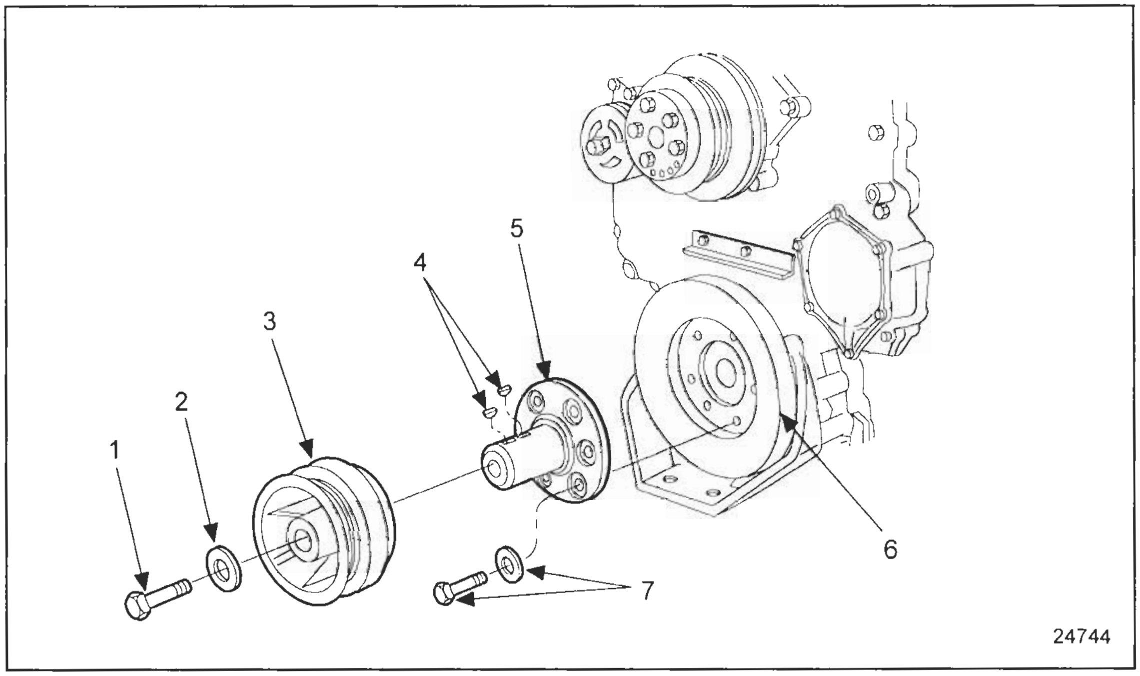


Figure 1-174 Crankshaft Pulley Installation

The crankshaft pulley is of the rigid design. Six bolt holes through the crankshaft pulley are equally spaced. A relief area is machined around each bolt hole and acts as a seating surface for the hardened washers. See Figure 1–175.

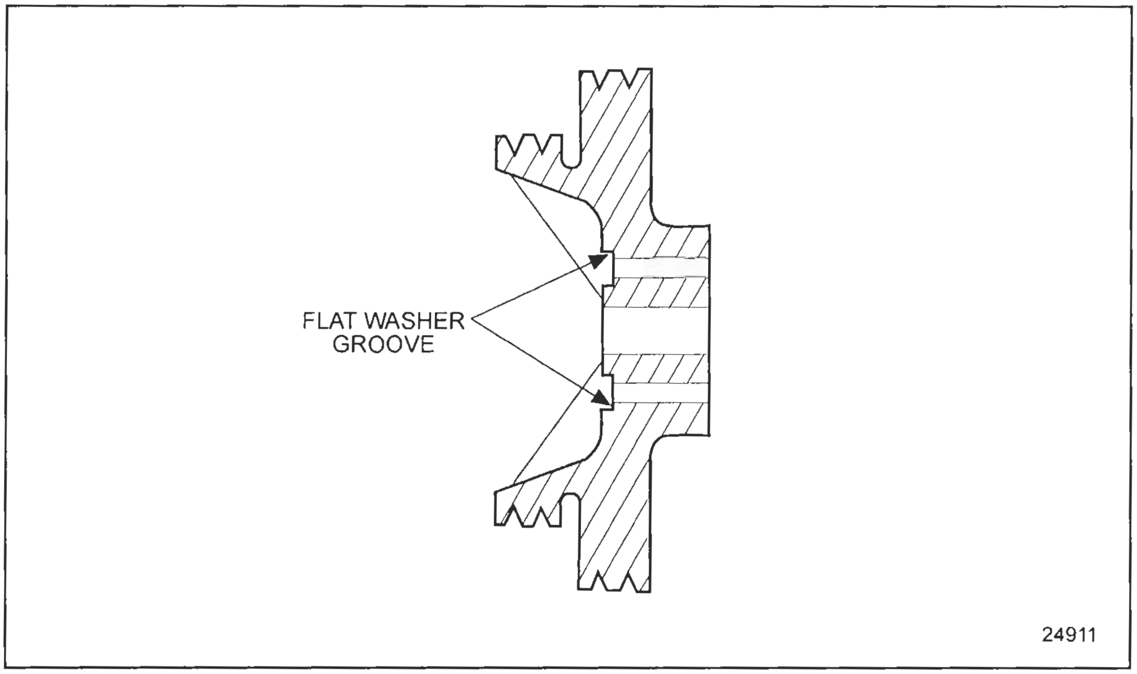


Figure 1–175 Crankshaft Pulley Cross–section

Four 12.7 mm (.50 in.) vee–type grooves in the crankshaft pulley provide drive belt seating surfaces.

A 3/4 in. square drive hole in the center of the crankshaft pulley allows the use of a 3/4 in. drive breaker bar or ratchet for barring the engine over. See Figure 1-176.

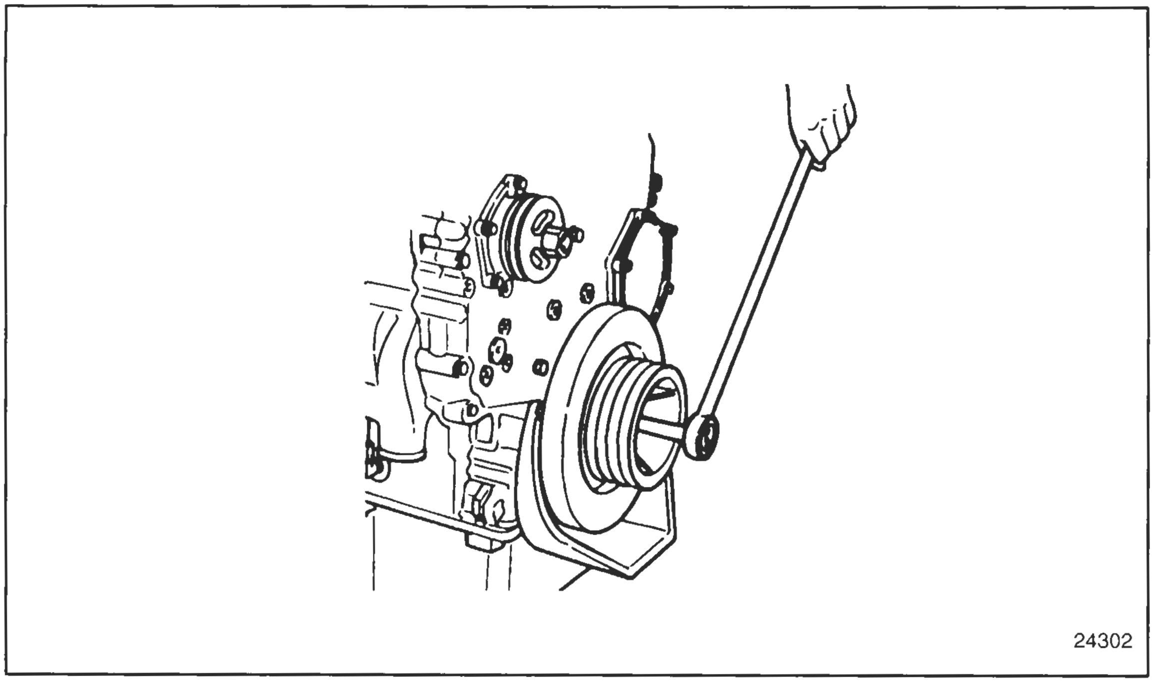


Figure 1–176 Barring Engine Over

1.13.1 Repair or Replacement of Crankshaft Pulley

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-177.

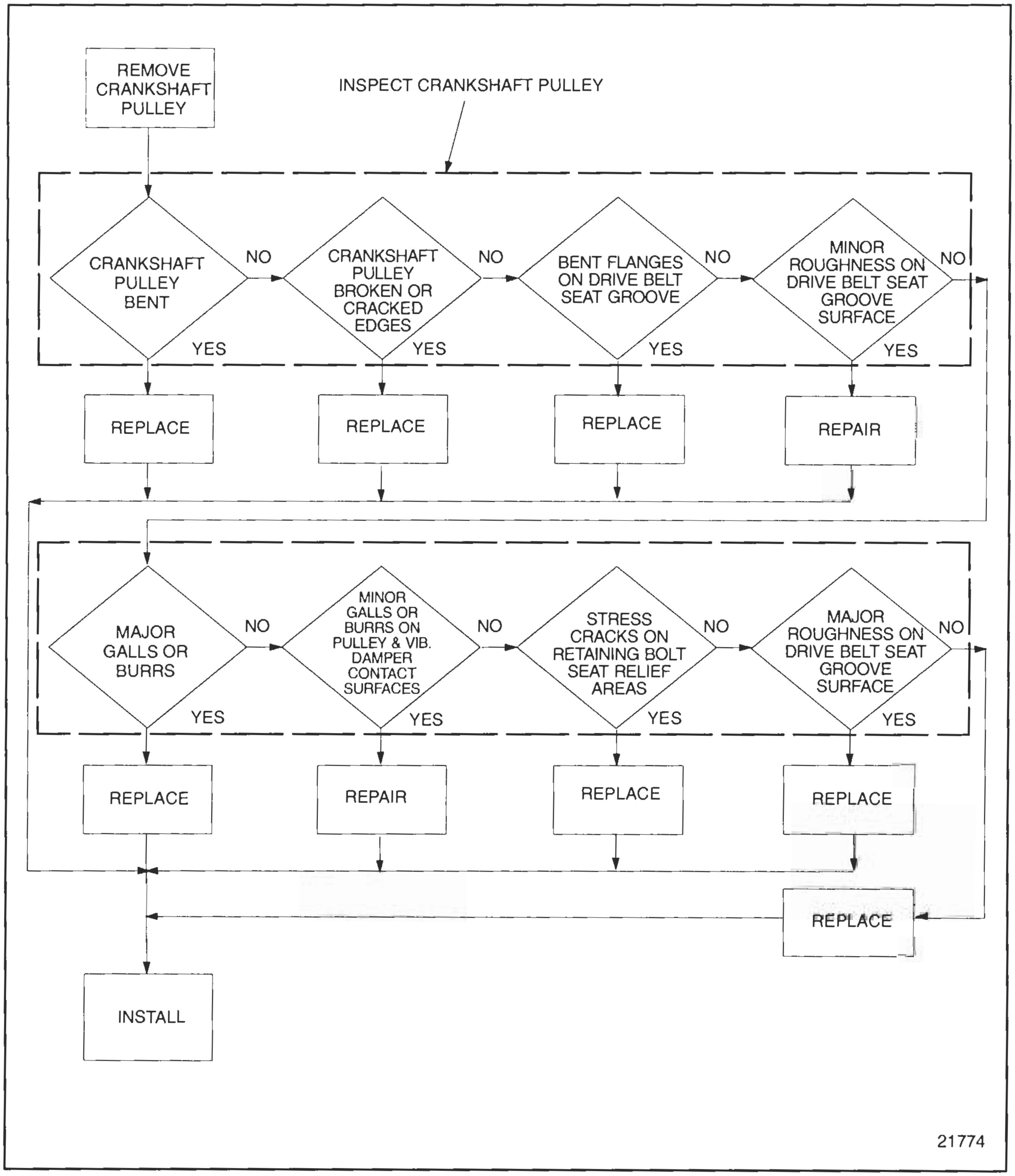


Figure 1-177 Flowchart for Repair or Replacement of Crankshaft Pulley

1.13.2 Cleaning and Removal Crankshaft Pulley

Precleaning is not necessary.

Remove a crankshaft mounted pulley as follows:

1. Remove the drive belts from the crankshaft pulley.
2. Remove the inspection plug in the bottom of the flywheel housing.
3. Install the flywheel lock, J 36375. See Figure 1-172.
4. Thread the center screw of the tool in until the top of the tool rests between two teeth of the flywheel ring gear.

NOTE:
It may be necessary to bar the engine over (using the square hole in the middle of the crankshaft pulley) so that the tool center screw is exactly between two teeth.

5. Tighten the knurled knob finger tight.
6. Remove two of the six crankshaft pulley-to-crankshaft attaching bolts and hardened washers that are 180° apart.
7. Install two guide studs, J 36235, to the holes the bolts were removed from.

NOTICE:
Use care when removing the crankshaft pulley as the vibration damper, which is slip fitted over a pilot diameter of the crank, may come off. If the damper is allowed to fall, internal damage to the damper will result.

8. Remove the remaining four crankshaft pulley bolts and hardened washers.
9. Remove the crankshaft pulley by sliding it off the guide studs.

NOTE:
Leave the guide studs in place to prevent the vibration damper from falling off.

Remove a spindle mounted pulley as follows:

1. Remove the drive belts from the crankshaft pulley.
2. Remove the inspection plug in the bottom of the flywheel housing.
3. Install the flywheel lock, J 36375. See Figure 1-172.
4. Thread the center screw of the tool in until the top of the tool rests between two teeth of the flywheel ring gear.

NOTE:
It may be necessary to bar the engine over (using the square hole in the middle of the crankshaft pulley) so that the tool center screw is exactly between two teeth.

5. Tighten the knurled knob finger tight.
6. Loosen the center bolt holding the pulley to the spindle.
7. With the pulley properly supported, remove the bolt and washer and pull the pulley off of the spindle.
8. Remove two of the six spindle–to–crankshaft attaching bolts and hardened washers that are 180° apart.
9. Install two guide studs, J 36235, to the holes the bolts were removed from.

NOTICE:
Use care when removing the spindle as the vibration damper, which is slip fitted over a pilot diameter of the crank, may come off. If the damper is allowed to fall, internal damage to the damper will result.

10. Remove the remaining four crankshaft pulley bolts and hardened washers.
11. Remove the spindle by sliding it off the guide studs.

NOTE:
Leave the guide studs in place to prevent the vibration damper from falling off.

1.13.2.1 Inspection of Crankshaft Pulley

Inspect the crankshaft pulley as follows:

1. Inspect the crankshaft pulley.

NOTICE:
A loose or bent crankshaft pulley, after extended operation, may result in a cracked crankshaft.

[a] Determine if the crankshaft pulley is bent, or has broken or cracked edges.

[b] If damage is detected, replace with a new part.

[c] If damage to the crankshaft pulley is extensive, refer to section 1.12.2.1, and inspect the vibration damper. Refer to section 1.7, and inspect the crankshaft.

2. Inspect the drive belt seat grooves.
   [a] Check drive belt seat grooves for bent flanges or a rough belt seating surface.
   [b] Smooth rough seating surfaces with an emery cloth or a stone.
   [c] If flanges are bent, replace the pulley.
3. Inspect the retaining bolt seat relief areas.
   [a] Check relief area for stress cracks.
   [b] If stress cracks are discovered, replace the pulley.
4. Inspect the pulley and vibration damper inner contact surfaces.
   [a] Check for galling or burrs. See Figure 1–178.
   [b] Minor galls burrs may be smoothed with an emery cloth.
   [c] If galls or burrs are major, the pulley will need to be replaced.

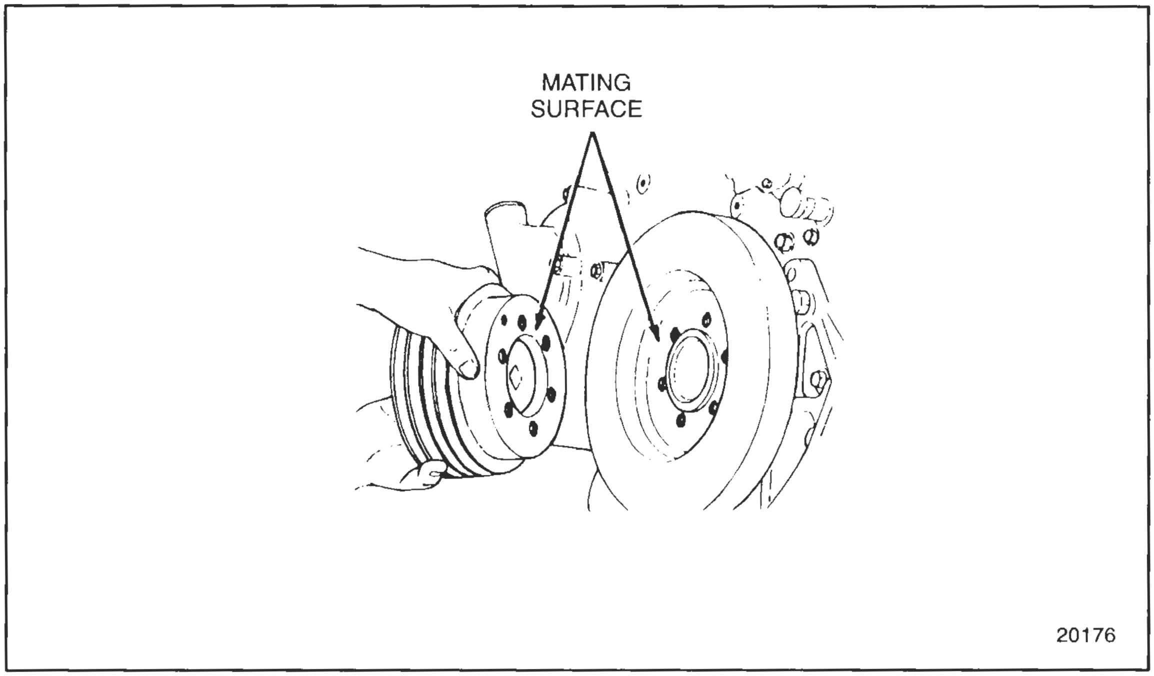


Figure 1–178 Crankshaft Pulley and Vibration Damper Inner Contact Surfaces

1.13.3 Installation of Crankshaft Pulley

Install a crankshaft pulley as follows:

1. If removed, install the flywheel lock, J 36375, to the inspection plug hole in the bottom of the flywheel housing. See Figure 1–172.
2. Thread the center screw of the tool until the tip of the tool rests between two teeth of the flywheel ring gear.

NOTE:
It may be necessary to bar the engine slightly using engine barring tool, J 36237, so that the tool center screw is exactly between two teeth.

3. Tighten the knurled knob finger tight.
4. Install two guide studs, J 36235, to two of the holes in the crankshaft that are 180° apart.
5. Install the crankshaft pulley to the crankshaft. The crankshaft pulley may be installed in any position.
6. Install four of the bolts, with hardened washers installed, through the pulley and damper and into the crankshaft. Tighten the bolts finger tight.
7. Remove the two guide studs.
8. Install the remaining two pulley bolts with hardened washers installed.
9. Tighten the six bolts to 182–210 N·m (134–155 lb·ft) torque. Proceed in a clockwise direction until all bolts are torqued.
10. Remove the flywheel lock tool.
11. Install the pipe plug to the inspection hole in the flywheel housing.
12. Install the drive belts to the crankshaft pulley. Adjust the belt tensions to the specifications. Refer to section 13.5.7.
13. Install any other components that were removed for this operation.
14. Refer to section 11.6 for verification of proper crankshaft pulley installation.

Install a spindle mounted pulley as follows:

1. Install the inspection plug in the bottom of the flywheel housing.
2. Install the flywheel lock, J 36375. See Figure 1–172.
3. Thread the center screw of the tool in until the top of the tool rests between two teeth of the flywheel ring gear.

NOTE:
It may be necessary to bar the engine over (using the square hole in the middle of the crankshaft pulley) so that the tool center screw is exactly between two teeth.

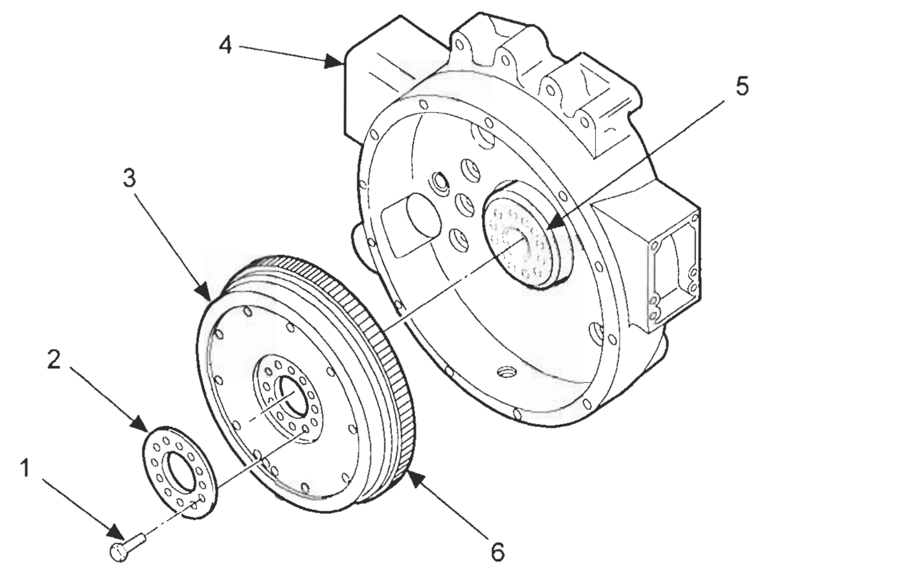
4. Tighten the knurled knob finger tight.
5. Install the spindle by sliding it off the guide studs.

NOTE:
Leave the guide studs in place to prevent the vibration damper from falling off.

6. Install the four spindle crankshaft bolts and hardened washers.
7. Remove the two guide studs, J 36235, from the holes.
8. Install the remaining two spindle–to–crankshaft attaching bolts and hardened washers that are 180° apart.
9. With the pulley properly supported, install the bolt and washer and pull the pulley to the spindle.
10. Tighten the center bolt holding the pulley to the spindle to 610 N·m (450 lb·ft) torque.
11. Install the drive belts from the crankshaft pulley.

1.14 FLYWHEEL

The flywheel is attached to the rear end of the crankshaft with twelve bolts. The bolt holes in the crankshaft and flywheel are equally spaced. The flywheel is not indexed to the crankshaft, and may be installed in any position. A scuff plate is used between the flywheel and the bolt heads to prevent the bolt heads from scoring the flywheel surface. See Figure 1–180.



1. Bolt (12)
2. Scuff Plate
3. Flywheel
4. Flywheel Housing
5. Crankshaft
6. Ring Gear

Figure 1–179 Typical Flywheel Assembly

A steel ring gear, which meshes with the starting motor pinion, is shrunk onto the rim of the flywheel. Refer to section 1.15.

The flywheel is machined to provide true alignment with the clutch. The clutch plate, if used, is bolted to the flywheel with 3/8 in.–16 bolts.

The flywheel must be removed for service operations such as replacing the starter ring gear, crankshaft oil seal, crankshaft or the flywheel housing.

1.14.1 Repair or Replacement of Flywheel

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1–180.

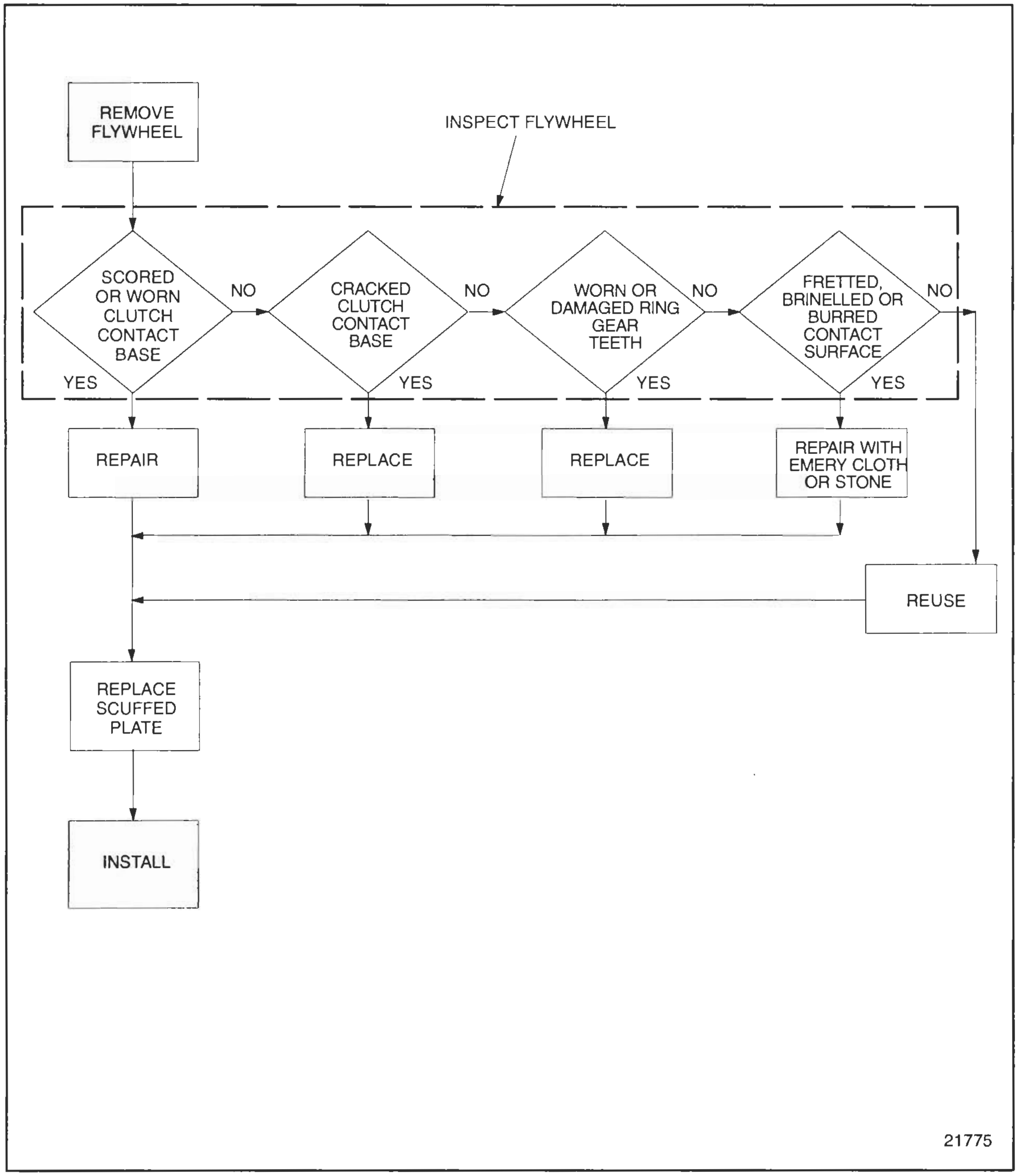


Figure 1–180 Flowchart for Repair or Replacement of Flywheel

1.14.2 Cleaning and Removal of Flywheel

Precleaning is not necessary.

Remove the flywheel as follows:

1. Remove the inspection plug in the bottom of the flywheel housing.
2. Install the flywheel lock, J 36375. See Figure 1-172.
3. Thread the center screw of the tool in until the tip of the tool rests between two teeth of the flywheel ring gear.

NOTE:
It may be necessary to bar the engine over (using the square hole in the middle of the crankshaft pulley) so that the tool center screw is exactly between two teeth.

4. Tighten the knurled knob finger tight.
5. Remove eleven of the twelve flywheel attaching bolts, leaving one bolt at the 12 o'clock position.
6. Install two flywheel guide studs, J 36235, through the flywheel and into the crankshaft at the 3 and 9 o'clock positions. See Figure 1-181.

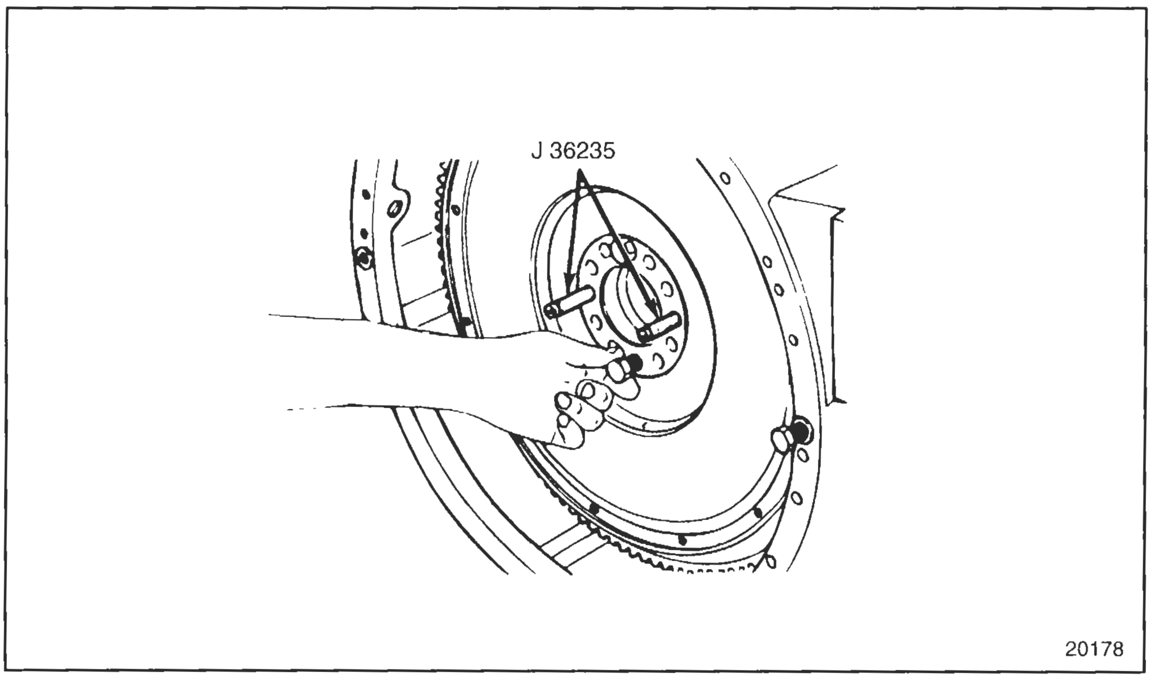


Figure 1-181 Flywheel Guide Studs

7. Attach the flywheel lifting tool, J 25026, or some other suitable lifting device, to the flywheel. See Figure 1–182.

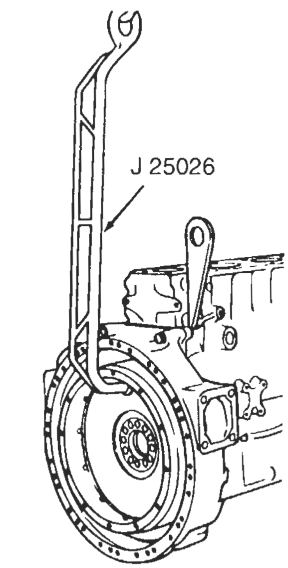


Figure 1–182 Flywheel Removal

8. Attach a chain hoist to the lifting tool.
9. Loosen, but do not remove the last flywheel attaching bolt.
10. Remove the flywheel lock.

CAUTION:

When removing the last flywheel attaching bolt, hold the flywheel against the crankshaft by hand to prevent it from slipping off the engine. The flywheel is NOT doweled to the engine. If the flywheel is allowed to fall, personal injury or serious damage to the flywheel could result.

11. Remove the last flywheel attaching bolt and scuff plate.
12. Remove flywheel.

1.14.2.1 Inspection of Flywheel

Inspect the flywheel as follows:

1. Inspect the clutch contact base of the flywheel.
   [a] Check clutch contact base for scoring, wear, or cracks.
   [b] If clutch contact face is scored or worn, the flywheel may be refaced.
   [c] If clutch contact face is cracked, the flywheel must be replaced.

NOTE:
Do not remove more than 0.508 mm (.020 in.) material from the flywheel. Maintain all of the radii when resurfacing.

2. Inspect the ring gear.
   [a] Check ring gear for excessively worn or damaged gear teeth.
   [b] If damaged gear teeth are detected, replace the ring gear. Refer to section 1.15.3.
3. Inspect crankshaft and flywheel contact surface.
   [a] Check the butt end of the crankshaft and flywheel contact surface for fretting, brinelling, or burrs. See Figure 1–183.
   [b] Lightly stone the contact surface to remove any fretting, brinelling, or burrs.

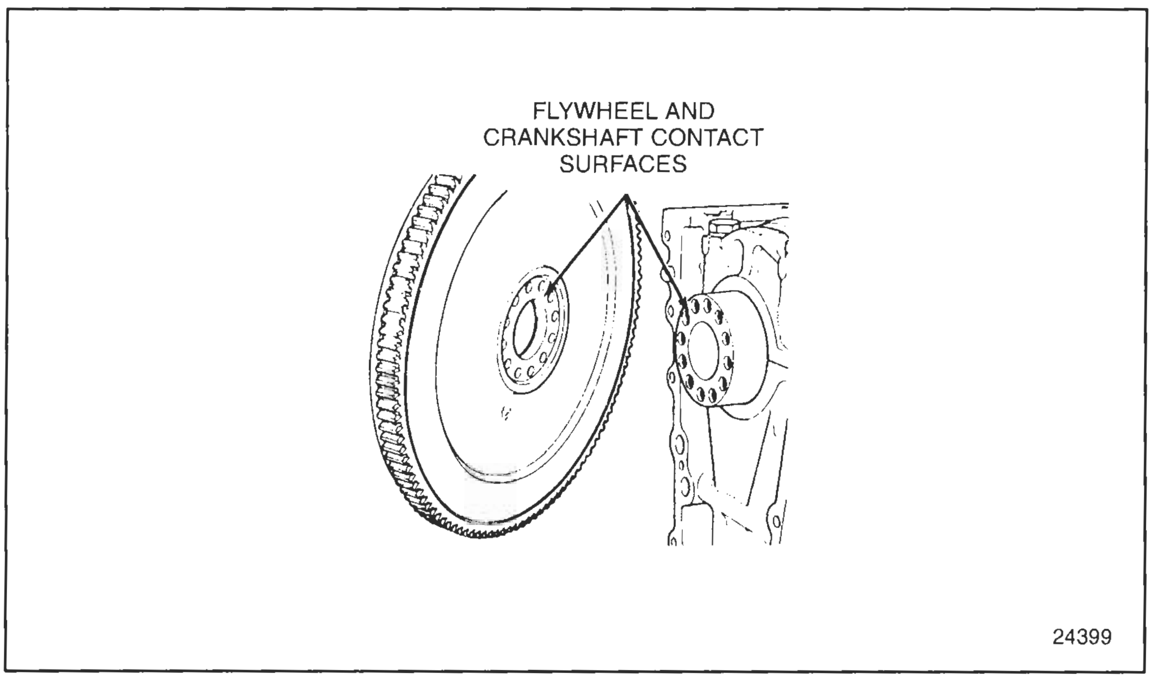


Figure 1–183 Crankshaft and Flywheel Mating Surfaces

1.14.3 Installation of Flywheel

Install the flywheel as follows:

1. Install two flywheel guide studs, J 36235, into two of the tapped holes in the crankshaft at the 3 and 9 o'clock position.
2. Attach the flywheel lifting tool and, using a chain hoist, position the flywheel in the flywheel housing. Align the flywheel bolt holes with the crankshaft bolt holes.

NOTICE:
A new scuff plate must be used whenever the flywheel is removed. Failure to replace the scuff plate may cause the flywheel bolts to loosen, even when torqued correctly.

3. Using a new scuff plate, install two bolts with International Compound No. 2 (or equivalent) through the plate 180° from each other
4. Install the flywheel lock, J 36375. See Figure 1-172.
5. Remove the flywheel lifting tool and guide studs.
6. Apply International Compound No. 2 (or equivalent) to the threads and to the bolt head contact area (underside) of the remaining bolts. The bolt threads must be completely filled with International Compound No. 2 (or equivalent). Any excess must be wiped off. See Figure 1-184.

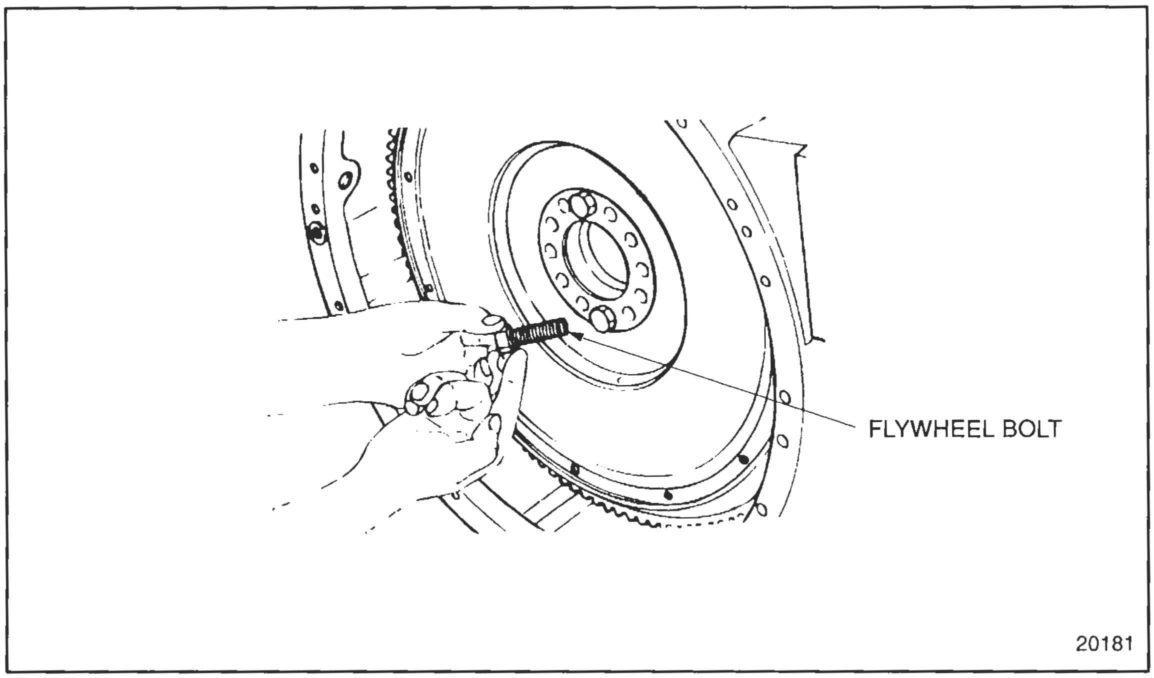


Figure 1-184 Flywheel Bolt Preparation

NOTE:
International Compound or equivalent must never be used between two surfaces where maximum friction is desired, as between the crankshaft and the flywheel.

7. Install the bolts and tighten them to 68 N·m (50 lb·ft) torque.
8. Turn the bolts an additional 120°, or 2 flats on a six-point bolt. See Figure 1–185.

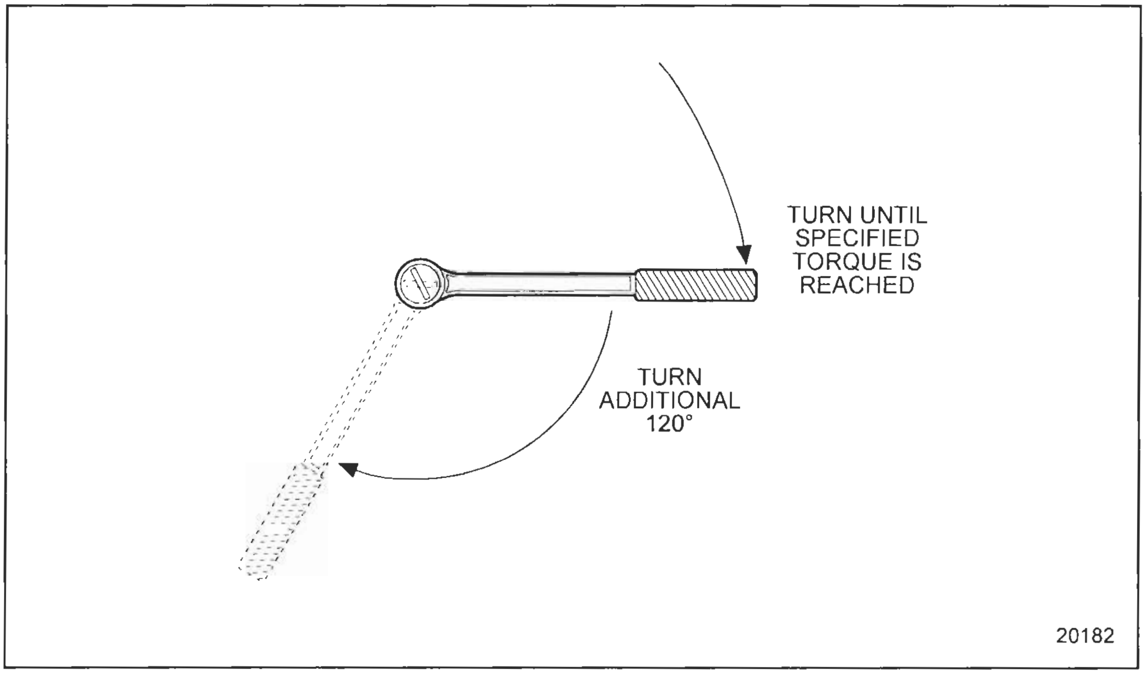


Figure 1–185 Torque Turn Limits

9. Remove the flywheel lock tool, J 36375.
10. Install the pipe plug and tighten to 45–56 N·m (33–41 lb·ft) torque.
11. Mount a dial indicator with a magnetic base on the flywheel housing. See Figure 1–186.

12. Check the runout of the flywheel at the clutch contact face.

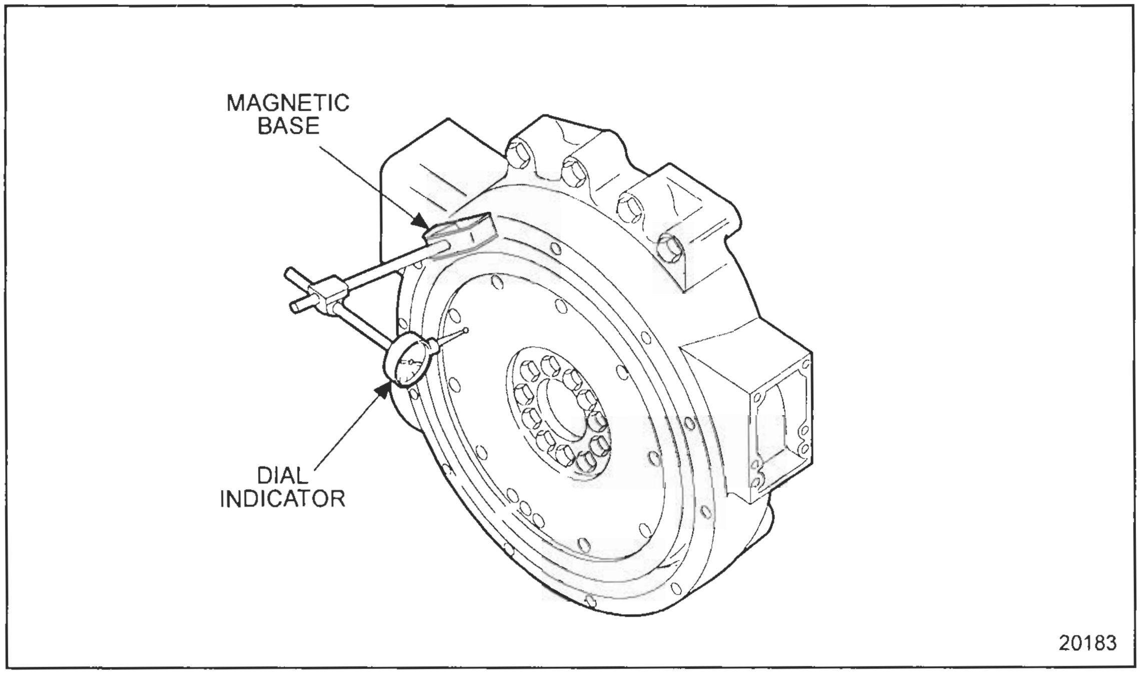


Figure 1–186 Measuring Flywheel Runout

13. The maximum allowable runout is 0.025 mm (.001 in.) total indicator reading per inch of radius (or 0.001 mm per millimeter of radius). The radius is measured from the center of the flywheel to the outer edge of the clutch contact face of the flywheel. Example: A 14 in. clutch would allow 0.175 mm (.007 in.) total indicator reading.
14. If maximum total indicator reading exceeds, 0.025 mm (.001 in.) per inch of radius, it may be necessary to repeat the assembly procedure until the cause can be detected and eliminated.

1.15 RING GEAR

The steel ring gear, which meshes with the starting motor pinion, is shrunk onto the rim of the flywheel.

1.15.1 Repair or Replacement of Ring Gear

If inspection of the flywheel indicated that ring gear replacement is necessary. See Figure 1–187.

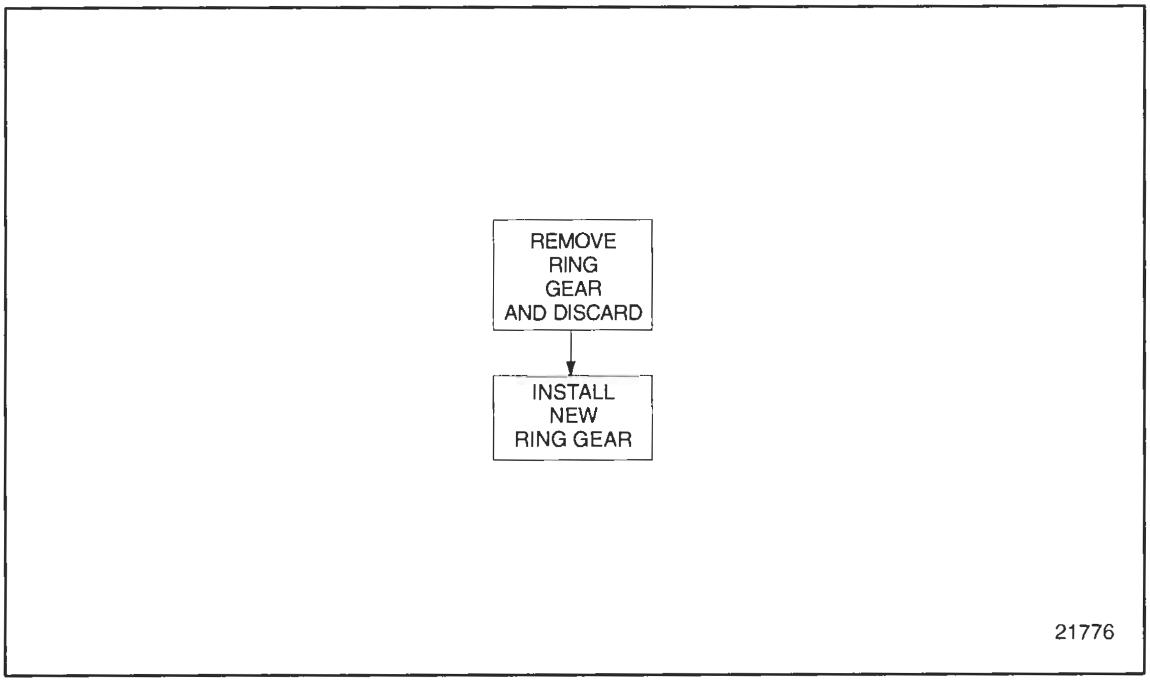


Figure 1–187 Flowchart for Repair or Replacement of Ring Gear

1.15.2 Cleaning and Removal of Ring Gear

Precleaning is not necessary.

Remove the ring gear as follows:

1. Using an acetylene torch, cut the ring gear 1/2 to 3/4 of the way through, without allowing the flame to touch the flywheel.
2. The uncut portion will now yield. Tap the ring gear to remove it from the flywheel.

1.15.3 Installation of Ring Gear

Install the ring gear as follows:

1. Support the flywheel, ring gear side up, on a solid flat surface.

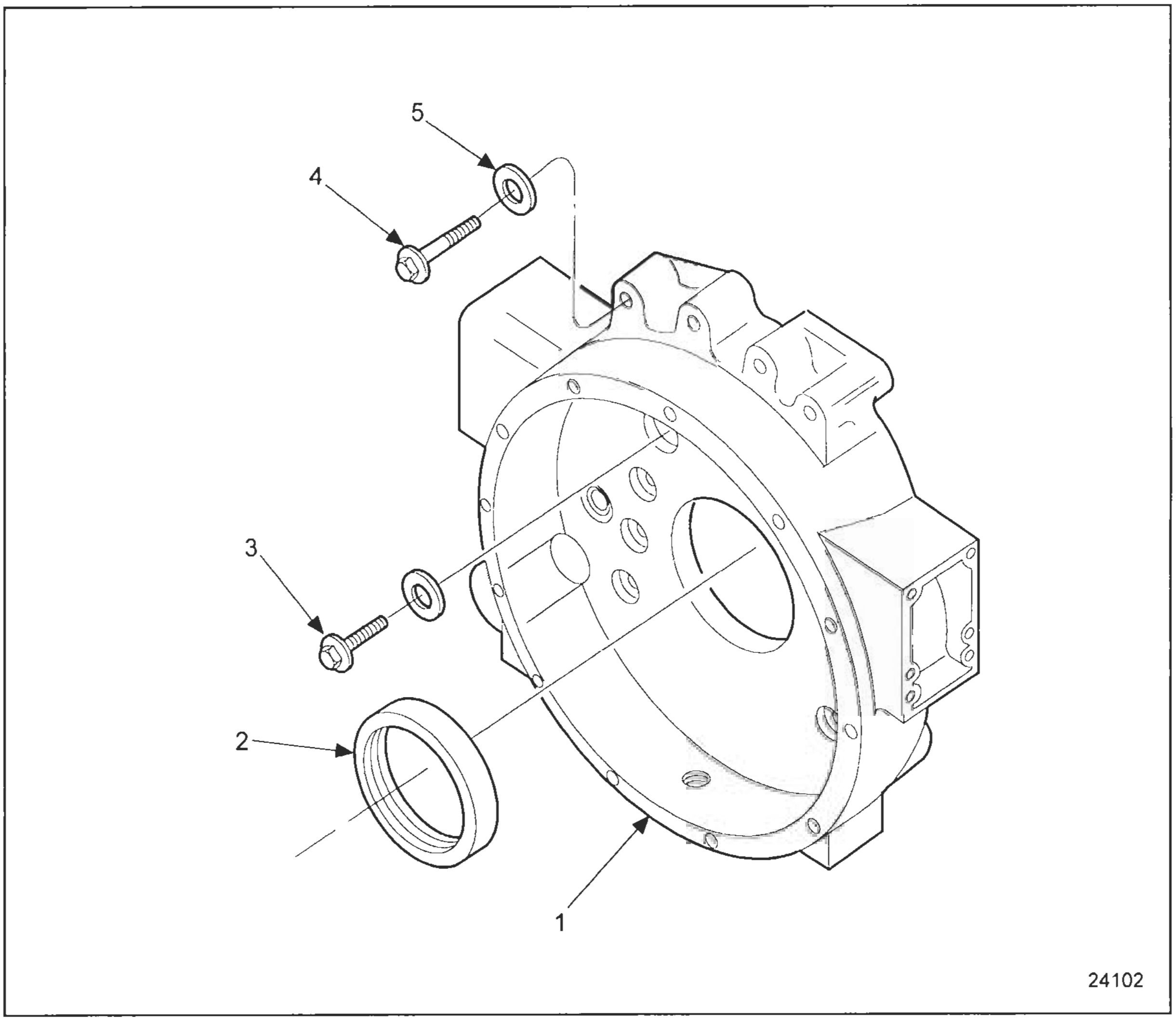
CAUTION:
To avoid personal injury, use lifting tools or heat resistant gloves when placing the HEATED ring gear on the flywheel.

NOTICE:
Do not under any circumstances, heat the gear over 204°C (399°F). Excessive heat may destroy the original heat treatment. Heat indicating "crayons" which are placed on the ring gear and melt at a predetermined temperature, may be obtained from most tool vendors. Use of these "crayons" will ensure against overheating the gear.

2. Rest the ring gear on a flat METAL SURFACE, and heat the gear uniformly with an acetylene torch, keeping the torch moving around the gear to avoid hot spots.
3. Use a pair of tongs to place the gear on the flywheel with the chamfer, if any, facing the same direction as on the gear just removed.
4. Tap the gear in place against the shoulder on the flywheel. If the gear cannot be tapped into place readily so that it is seated all the way around, remove it, and apply additional heat.

1.16 FLYWHEEL HOUSING

The flywheel housing is a one-piece casting mounted against the rear of the cylinder block. It provides a cover for the flywheel and serves as a support for the cranking motor and the transmission. See Figure 1-188.



1. Flywheel Housing
2. Crankshaft Rear Oil Seal
3. Inner Bolt (8 short)
4. Outer Bolt (4 long)
5. Washer (12)

Figure 1-188 Flywheel Housing and Related Parts

The crankshaft rear oil seal, which is pressed into the housing, may be removed or installed without removing the housing. Refer to section 1.8.2.

1.16.1 Repair or Replacement of Flywheel Housing

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1–189.

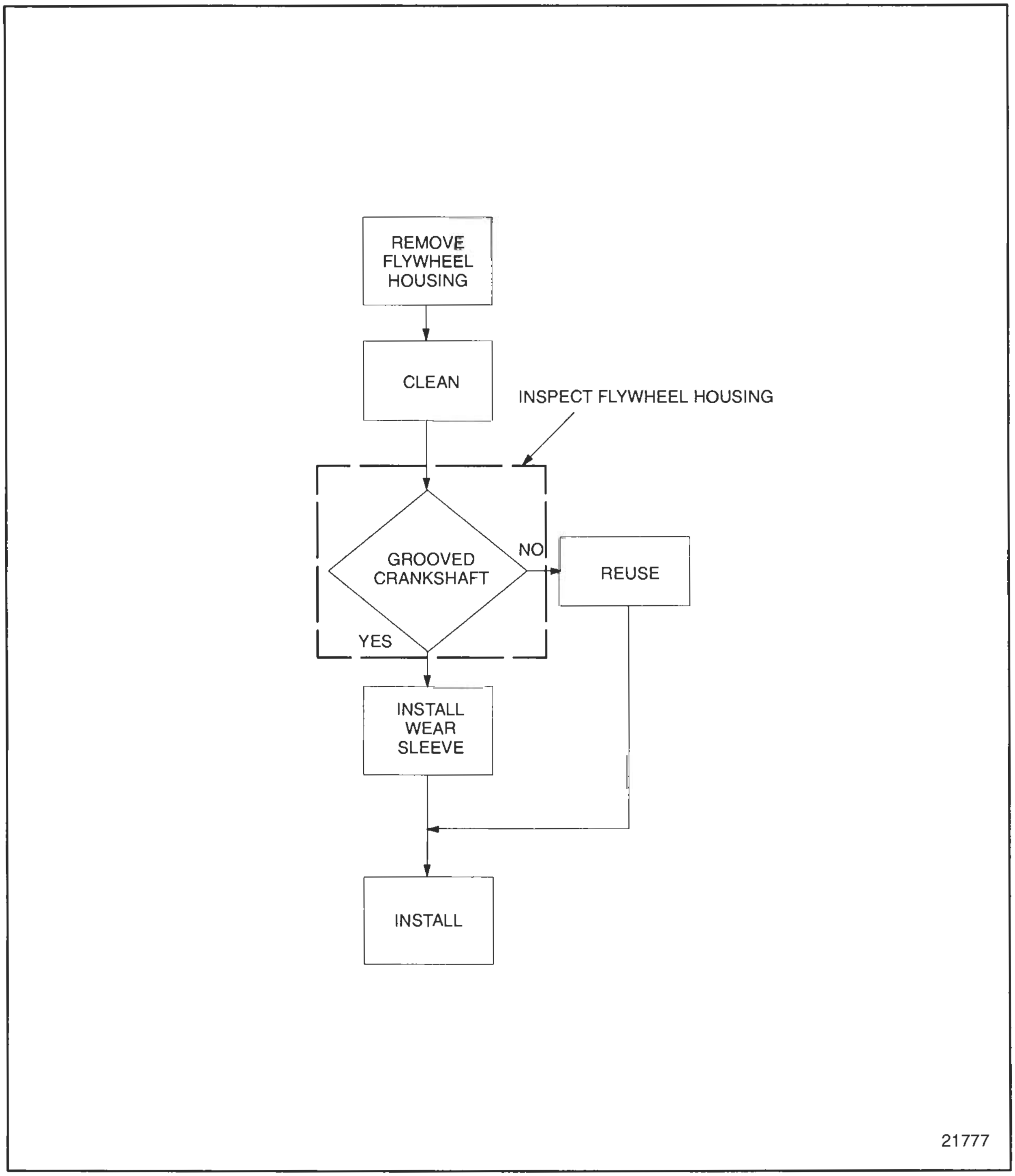


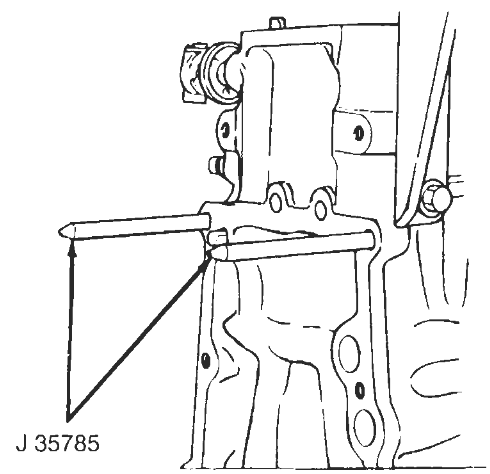
Figure 1–189 Flowchart for Repair or Replacement of Flywheel Housing

1.16.2 Cleaning and Removal of Flywheel Housing

Precleaning is not necessary.

Remove the flywheel housing as follows:

1. If the engine is removed from the vehicle, mount the engine on an overhaul stand. Refer to section 1.1.
2. Drain engine oil and remove the oil pan. Refer to section 3.9.2.
3. Remove the flywheel and scuff plate. Refer to section 1.14.2.
4. Remove the four long outer bolts and the eight short inner bolts that secure the flywheel housing to the engine. See Figure 1–188.
5. To guide the flywheel housing until it clears the end of the crankshaft, thread two guide studs, J 35785, into the cylinder block. See Figure 1–190.



NOTE: The illustration is shown with the flywheel housing already removed for clarity.

Figure 1–190 Pilot Stud Installation

6. Thread eye bolts into the tapped holes in the side pads of the flywheel housing.
7. Attach a suitable sling to the eye bolts. then strike the front face of the housing alternately on each side with a soft hammer to loosen and work it off the dowel pins.
8. Strike the front face of the housing alternately on each side with a soft hammer to loosen and work it off the dowel pins.
9. Remove and discard the crankshaft rear oil seal.

10. Remove all sealing material from the flywheel housing. Refer to, "Gasket Eliminator Removal" in the General Information section of this manual.

1.16.2.1 Inspection of Flywheel Housing and Rear Oil Seal Area of Crankshaft

Inspect the flywheel housing as follows:

1. Inspect flywheel housing for cracks and any other damage.
   [a] If sealing surface is damaged, repair with emery cloth.
   [b] If cracked, repair is not possible.
2. Inspect the crankshaft where the rear oil seal makes contact.
   [a] Check for groove in crankshaft.
   [b] If crankshaft is grooved, install a wear sleeve over the crankshaft end. An oversized I.D. rear oil seal must be used with the rear sleeve.

1.16.3 Installation of Flywheel Housing

Install the flywheel housing as follows:

1. Apply a continuous 1.6 mm (1/16 in.) bead, of gasket eliminator, PT-7276 (Loctite 51580), or equivalent, to the cylinder block where it mates with the flywheel housing. See Figure 1-191.

NOTE:
Whenever crankshaft rear seal is put over the crankshaft, use crankshaft oil seal expander, Refer to section 1.8.

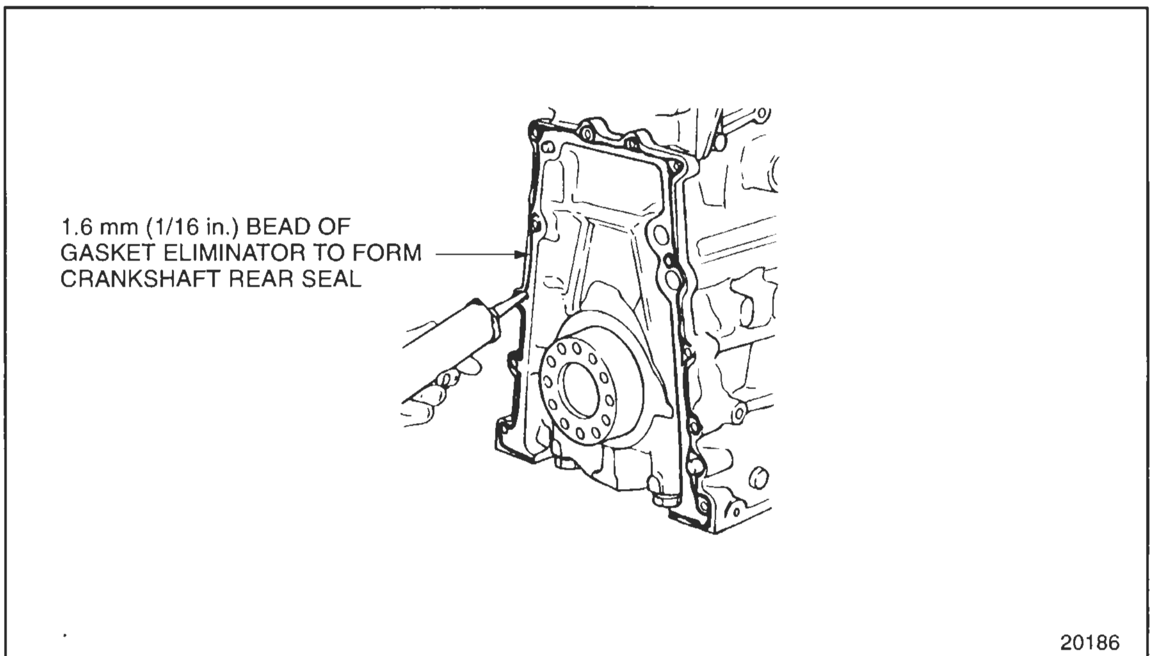


Figure 1-191 Gasket Eliminator Installation

2. Thread two aligning studs, J 35785, into the cylinder block to guide the housing in place. See Figure 1–190.
3. Support the housing and position it over the crankshaft and against the cylinder block.
4. Install all of the housing bolts in their proper location, finger tight.
5. Remove the pilot studs.
6. Tighten the eight short and four long flywheel housing bolts to 101–126 N·m (75–93 lb·ft) torque, using the proper tightening sequence. See Figure 1–192.

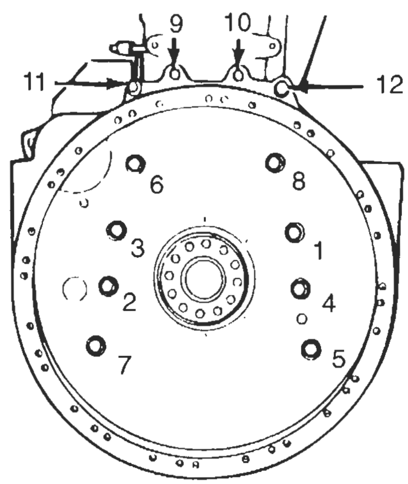


Figure 1–192 Flywheel Housing Bolt Torque Sequence

7. Install the crankshaft rear main oil seal. Refer to section 1.8.5.
8. Install the flywheel. Refer to section 1.14.3.
9. Install oil pan. Refer to section 3.9.3.
10. Refill with engine oil. Refer to section 13.5.1.

1.16.3.1 Test for Flywheel Housing Bore Concentricity

Check the flywheel housing bore concentricity, and bolting flange run–out with tool set, J 9737–C, as follows:

1. Thread the base post, J 9737–3, into one of the tapped holes on the outer edge of the flywheel.
2. Assemble the dial indicators on the base post with the attaching parts provided in the tool set.
3. Position the dial indicators straight and square with the flywheel housing bell face and inside bore of the bell. Make sure each indicator has adequate travel in each direction. See Figure 1–193.

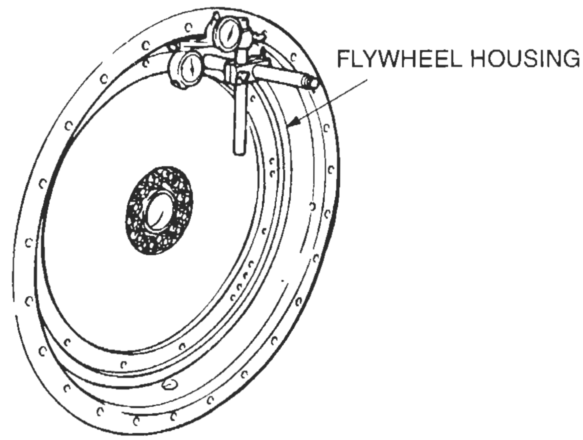


Figure 1–193 Measuring Flywheel Housing Bore Concentricity and Bolting Flange Runout

4. Tap the end of the crankshaft (not the crankshaft pulley) with a soft hammer to force it toward one end of the block to ensure end play is in one direction only.
5. Adjust each dial indicator to read zero at the twelve o'clock position.

6. Rotate the crankshaft one complete revolution, taking readings at 90° intervals (4 readings each for the bore and bolting flange face). See Figure 1-193.

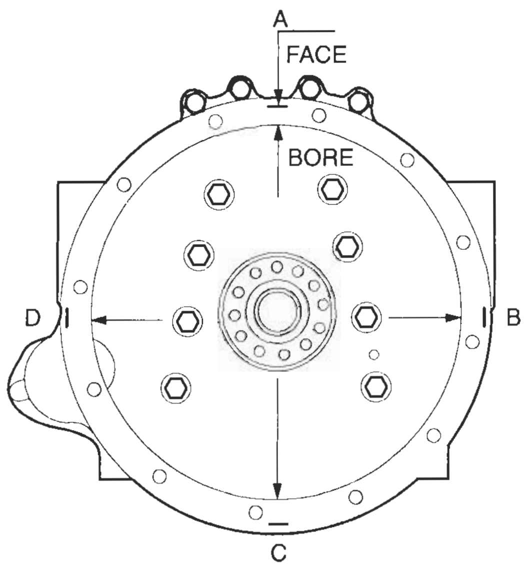
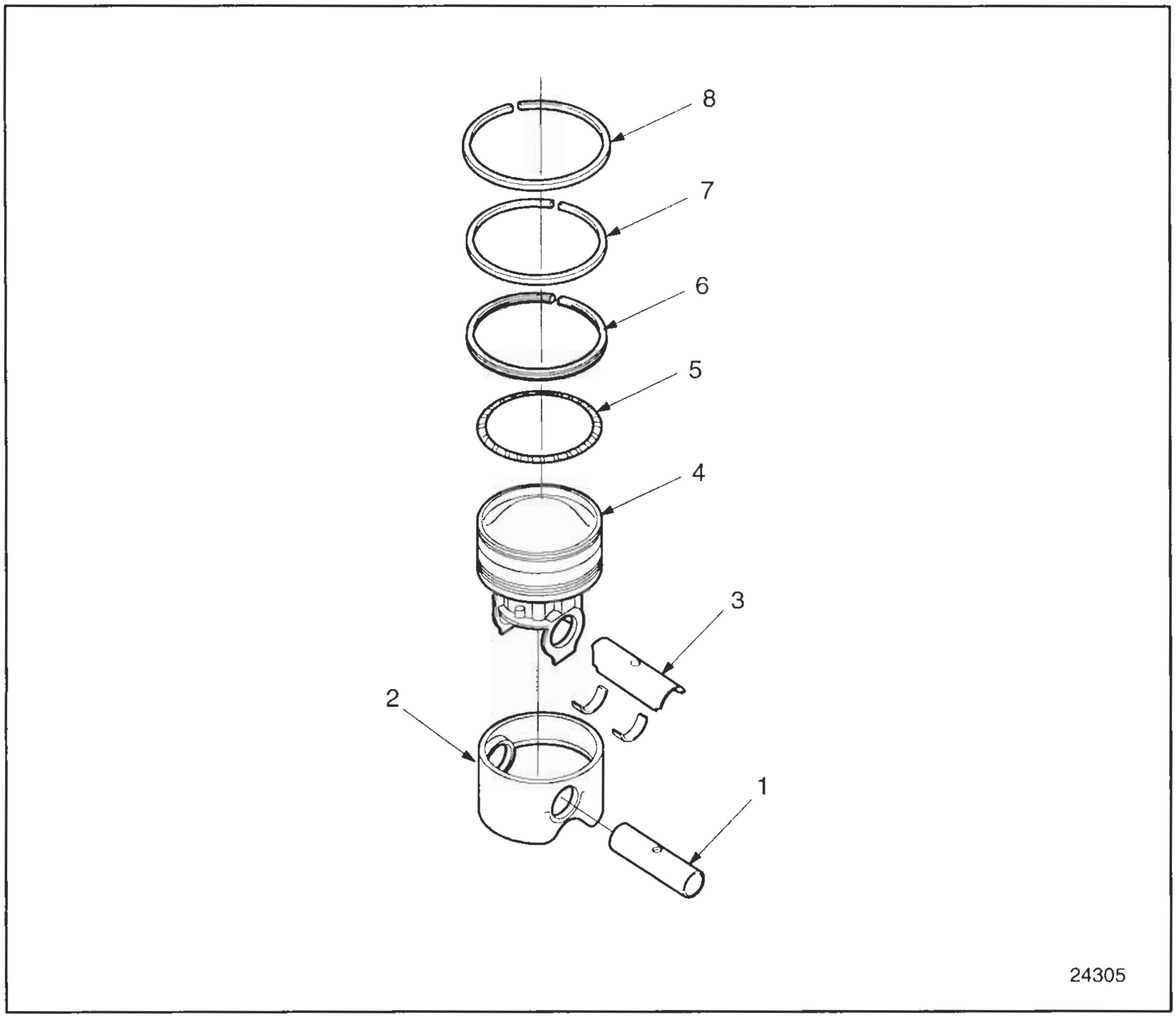


Figure 1–194 Flywheel Housing

7. Remove the wrench or cranking bar before recording each reading to ensure accuracy.
   [a] The maximum total indicator reading must not exceed 0.33 mm (.013 in.) for either the bore or the face.
   [b] If the runout exceeds the maximum limits, remove the flywheel and flywheel housing and check for dirt or foreign material between the flywheel housing and the cylinder block or oil pan.
8. Clean the mating surfaces once again. Refer to section, "Gasket Eliminator Removal" in the General Information section of this manual.
9. Install flywheel housing. Tighten the eight short and four long bolts to 101–126 N·m (75–93 lb·ft) torque, using the tightening sequence. See Figure 1-192.
10. Install the flywheel. Refer to section 1.14.3.
11. Check the runout again. If necessary, replace the flywheel housing.

1.17 PISTON AND PISTON RING

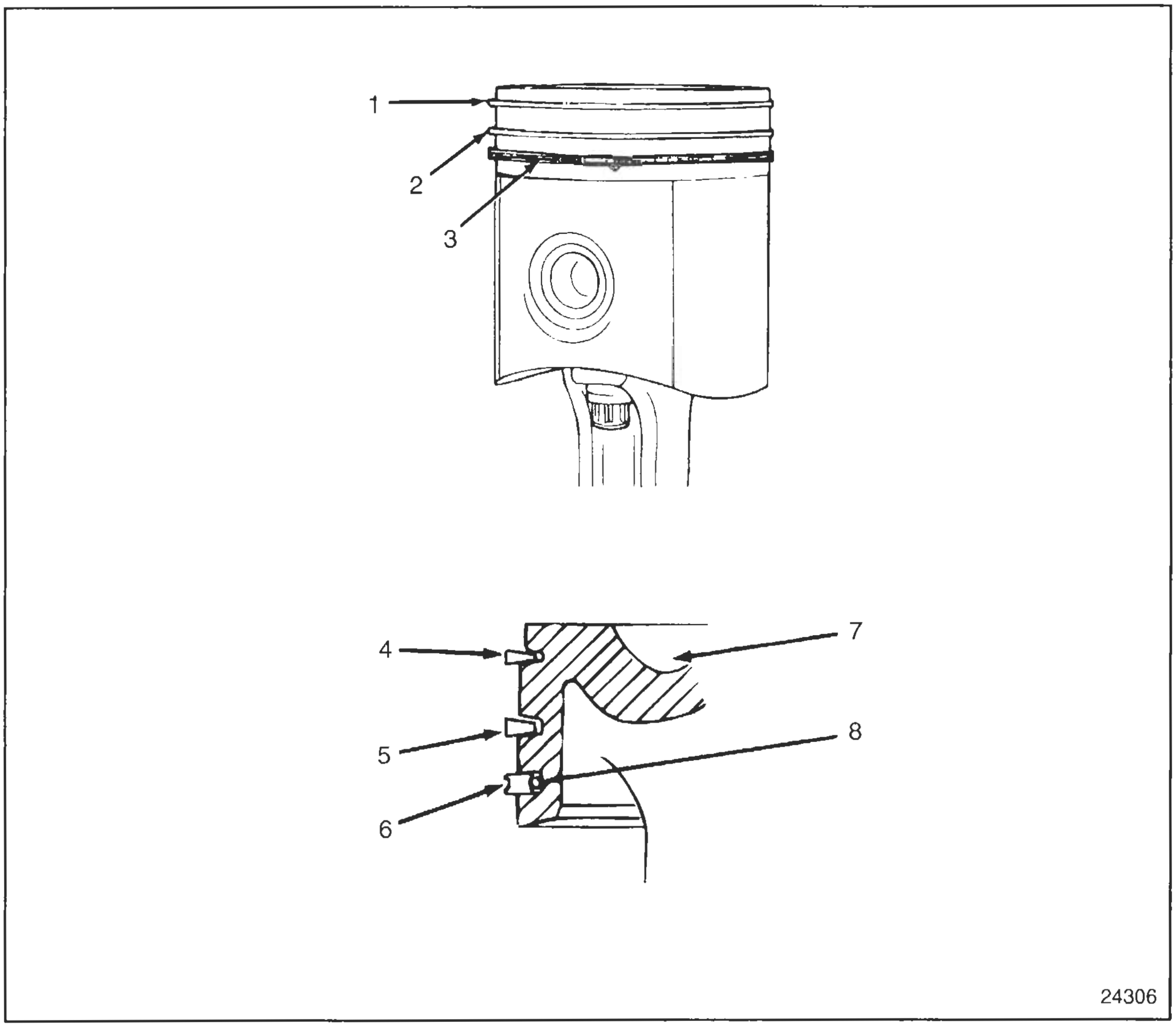
The cross–head piston is a two–piece piston consisting of a dome and a skirt. The dome and skirt are held together by the piston pin. Ring grooves are machined in the piston dome. See Figure 1–195.



1. Piston Pin
2. Piston Skirt
3. Three–piece Bushing
4. Piston Dome
5. Oil Ring Expander
6. Oil Control Ring
7. Compression Ring
8. Fire Ring

Figure 1–195 Piston and Related Parts

Each piston is fitted with a fire ring, compression ring and one-piece oil control ring with expander. See Figure 1-196, and see Figure 1-197.



1. Fire Ring
2. Compression Ring
3. Oil Control Ring
4. Fire Ring*
5. Compression Ring*
6. Oil Control Ring
7. Piston Dome
8. Oil Ring Expander

* Note: Identification Mark to Face Top of Dome

Figure 1-196 Piston Ring Location

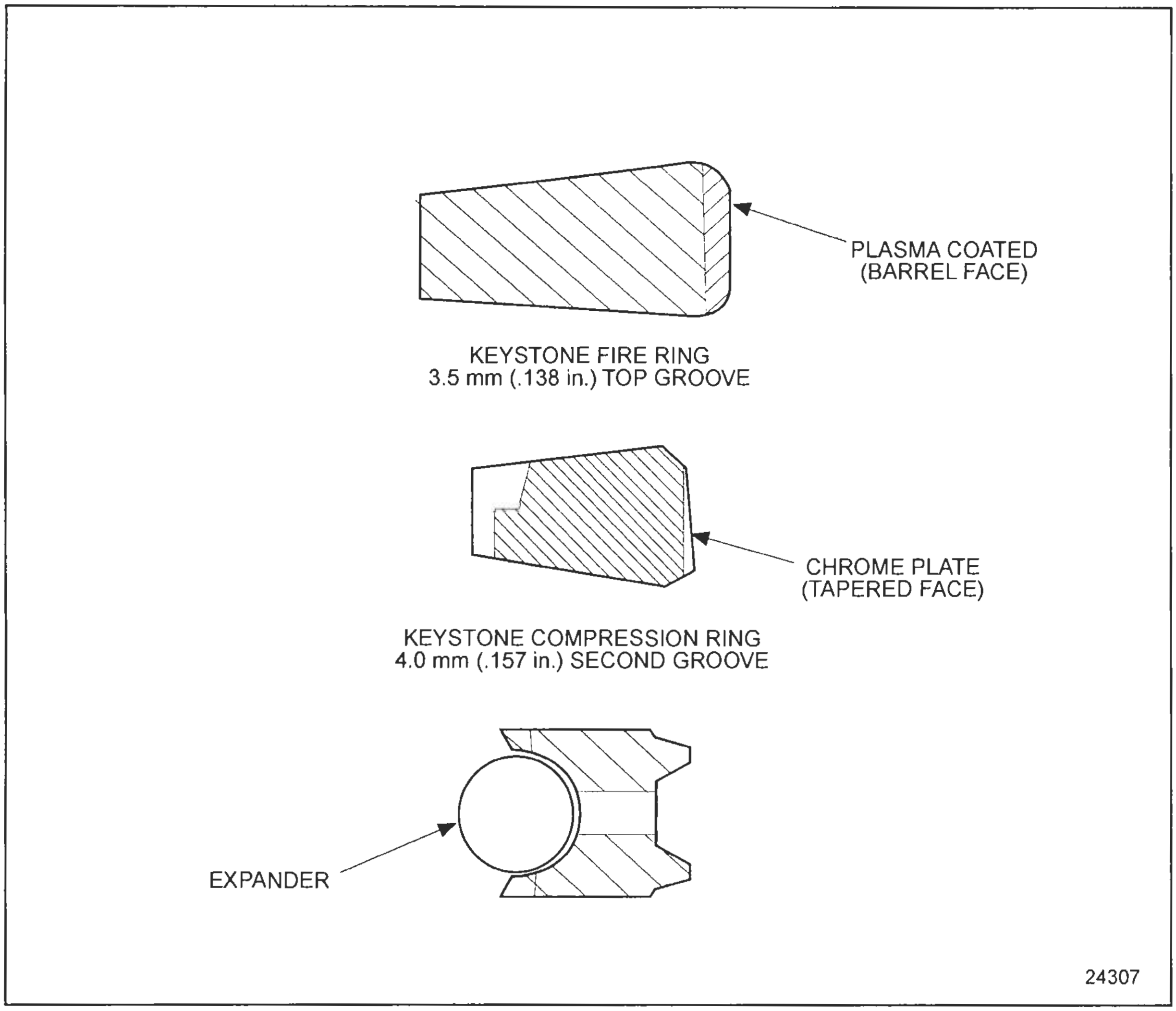


Figure 1–197 Piston Ring Packs

The top two rings are identified by a small indentation mark on the top side. See Figure 1–198. All three rings are chrome–plated on the face.

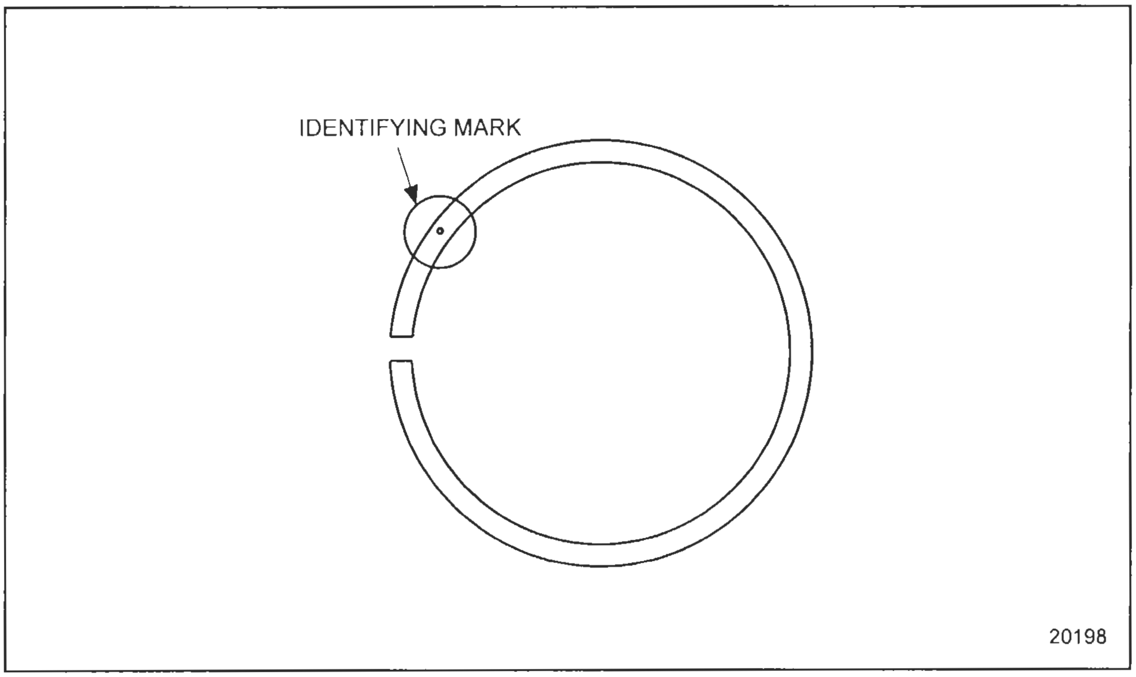


Figure 1–198 Fire and Compression Ring Identification

A one–piece oil control ring is used in the third groove. The expander is of Spira–Lox construction.

Two oil relief channels are drilled into the oil ring groove area, on each side of the dome, just above the piston pin bore. These channels are not drilled through the piston. The channels help the excess oil, scraped from the cylinder walls, return to the crankcase. See Figure 1–199.

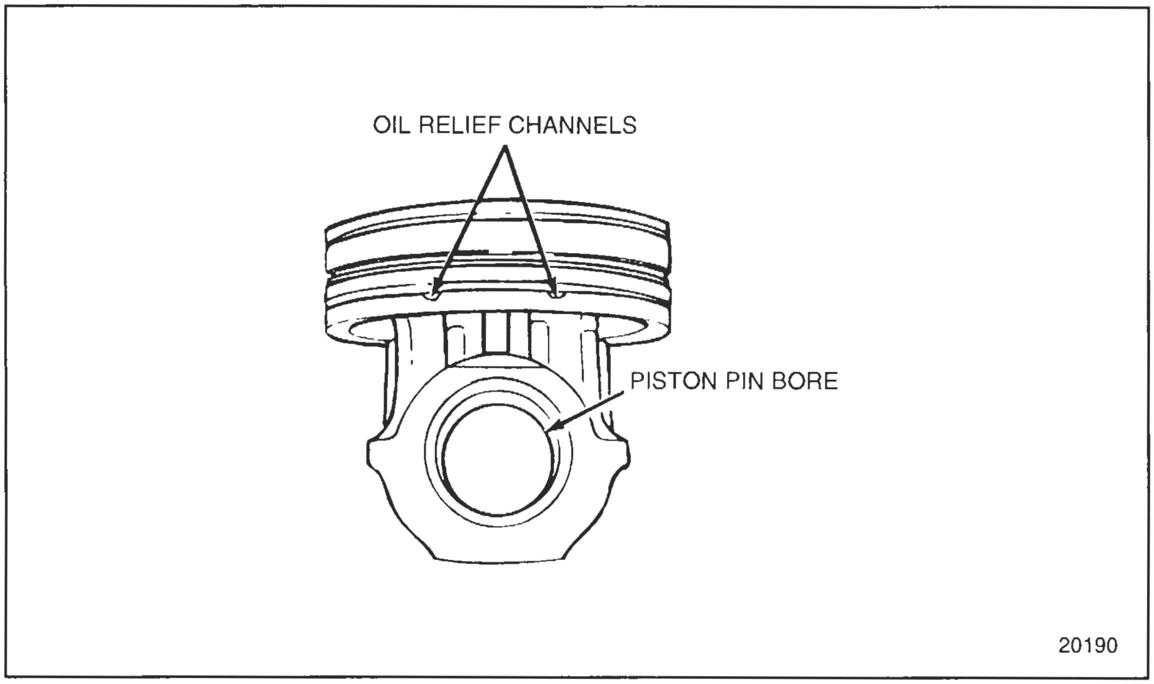


Figure 1–199 Piston Oil Relief Channels

Two dome designs are used in Series 50 Engines. The earlier design has a non–serviceable bearing. The piston dome and piston pin bearing of the most recent design are separate parts and may be serviced separately.

Two special bolts and spacers are used to attach the connecting rod to the piston pin.

The solid–core piston pin has a drilled hole through the center to provide lubricating oil to the piston dome for cooling. A threaded hole on each side of the oil hole receives the connecting rod attaching bolts. See Figure 1–200.

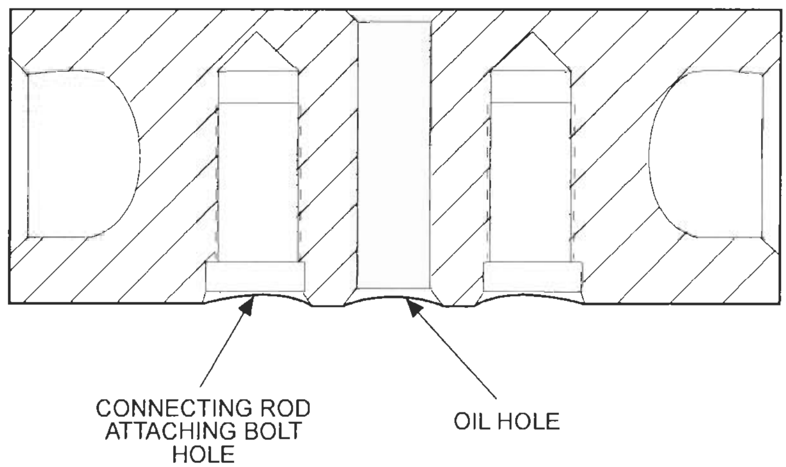


Figure 1–200 Piston Pin Cross–section

Internal parts of the piston are lubricated and cooled by the engine lubricating oil. Oil is pressure–fed up the drilled passage in the connecting rod, through the piston pin, then through the center hole in the bearing to the underside of the piston dome. A portion of the oil lubricates the piston pin and bearing.

During engine operation, gas loads pushing down on the piston dome are taken directly by the piston pin and bearing. The piston skirt, being separate, is free from vertical load distortion. Thermal distortion is also reduced as the piston dome expands. As the connecting rod swings to one side on the downward travel of the piston, the major portion of the side thrust is taken by the piston skirt.

1.17.1 Repair or Replacement of Piston and Piston Ring

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-201.

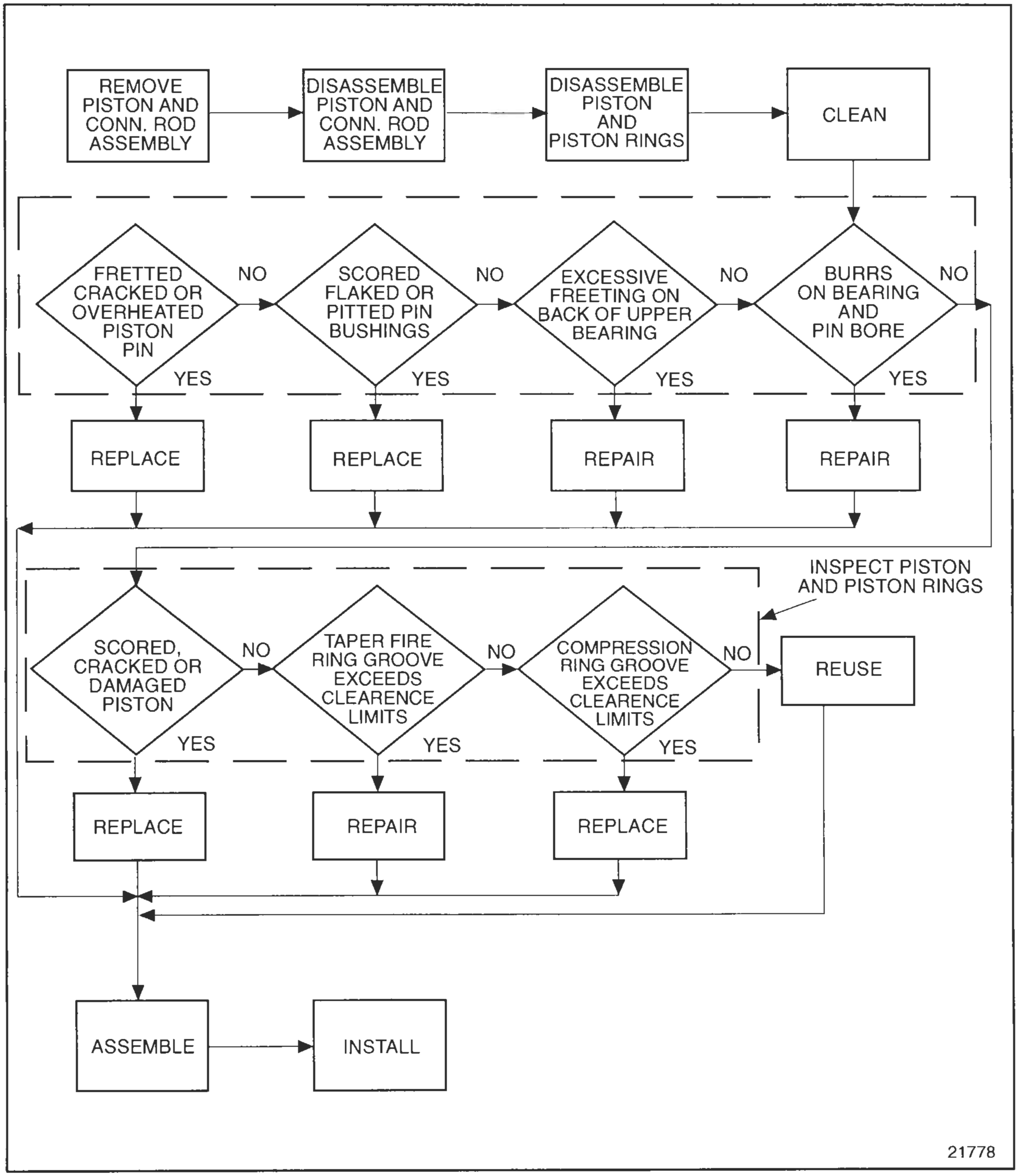


Figure 1-201 Flowchart for Repair or Replacement of Piston and Piston Rings

1.17.2 Cleaning and Removal of Piston and Piston Ring

Refer to section 1.18.2 for piston and connecting rod assembly removal procedure.

1.17.3 Disassembly of Piston and Piston Ring

Disassemble the piston and piston rings as follows:

1. Remove the piston rings with tool J 22405–02. See Figure 1–202.

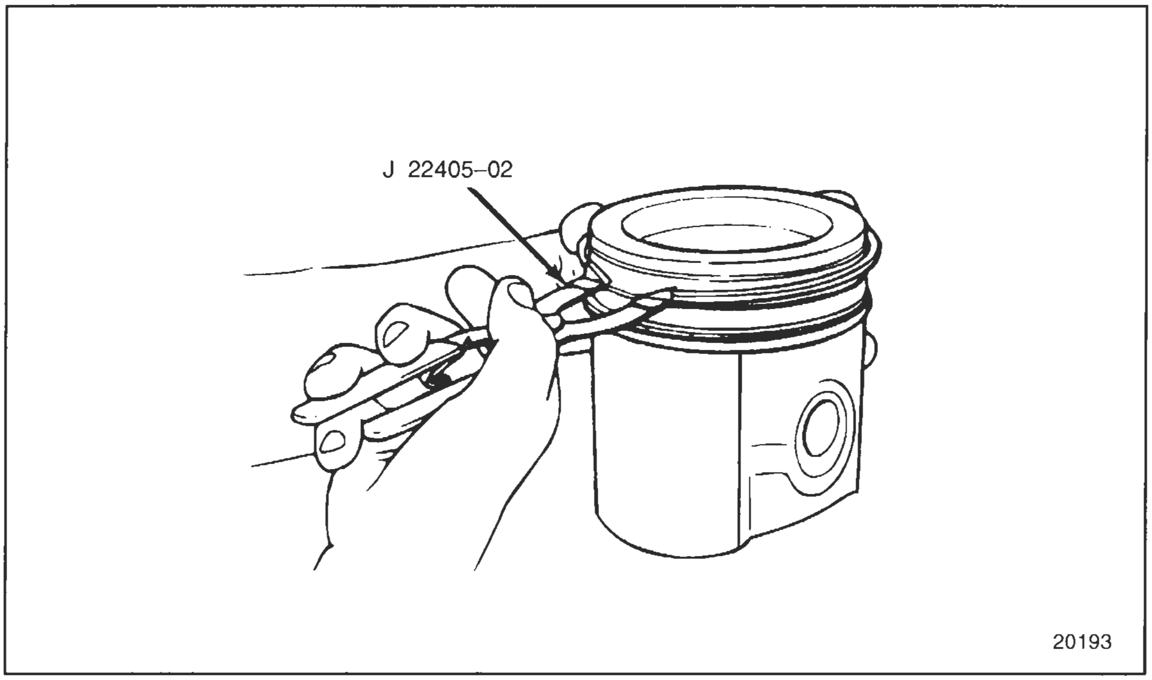


Figure 1–202 Removing Piston Rings

NOTICE:
The pin, bushing, skirt and dome must be match–marked to assure proper position and orientation.

2. Withdraw the piston pin and mark or etch the front of the piston, so they can be returned to the correct cylinder location.
3. Separate the piston skirt from the piston dome and mark or etch the front of the dome ear and skirt, so they can be returned to the correct location.
4. Remove the piston pin bearings, marking the front of them, so they can be returned to the correct location.

NOTE:
The lower pin bore bearings are removed from the pin bore first, by pushing the bearing legs outward by hand at the split lines from inside the dome saddle ear. The upper bearing may be held in the bore by oil on the back of the bearing, making removal from the pin bore by hand difficult.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

NOTICE:

Prying between the bearing back and dome bore may damage the dome saddle bore or raise burrs which will make installation of new bearings difficult.

DDC recommends that compressed air be directed between the dome pin bore and back of the bearing at one end until the bearing pops up out of the bearing retaining hole.

1.17.3.1 Inspection of Piston and Piston Ring

Clean the piston and piston rings prior to inspection as follows:

NOTICE:
Do not attempt to clean the piston skirt by glass beading. It will remove the tinplating. Do not refinish or polish the piston pin.

1. Clean the piston components with fuel oil.

CAUTION:
To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

2. Dry the piston components with compressed air.
3. If fuel oil does not remove the carbon deposits, use a chemical solvent that will not harm the tinplate on the piston skirt.

CAUTION:
To avoid personal injury when blow drying, wear adequate eye protection.

NOTICE:
After cleaning, do not leave glass beads in the piston dome. **Do not allow the glass beading to contact any area of the piston pin bushing or pin bore.** Glass beading will remove the tinplating.

4. The piston dome, including the compression ring grooves, is not tin-plated and may be wire-brushed to remove any hard carbon. Glass beading can be used to clean a piston dome. Micro Bead Glass Shot MS-M (.0029-.0058 in.) is recommended. Allowable air pressure is 552-689 kPa (80-100 lb/in.^{2}).

NOTE:
Do not wire–brush the piston skirt.

5. Clean the ring grooves with a suitable tool or a piece of an old compression ring that has been ground to a bevel edge.
6. Clean the inside surfaces of the piston dome and skirt and the oil relief channels in the oil ring grooves.

Inspect the piston and piston rings as follows:

1. Inspect the piston skirt and dome.
   [a] Check the skirt and dome for score marks, cracks, damaged ring grooves or overheating indications.
   [b] If any of these indications are present, the piston must be replaced.

NOTE:
Burn spots may indicate an obstruction in the connecting rod or piston pin oil passage.

2. Inspect the tapered fire ring groove (top) in the piston dome.
   [a] Using the piston ring land step gage, J 35884–A or J 38609–A, check tapered fire ring groove. See Figure 1–203.
   [b] Insert the center tang of the tool gage into the top piston ring groove ash. See Figure 1–203.
   [c] Hold the tool at a 90° angle to the ring groove to prevent false readings.
   [d] With the center tang into the ring groove as far as it will go, there should be no contact of the piston with the shoulder of the gage. If the gage makes contact at point A or point B, the fire ring groove is worn beyond usable limits. Check the groove clearance at 4 spots, at 90° intervals. Measure the ring land parallel to and at 90° to the wrist pin.
   [e] If fire ring groove is worn beyond usable limits, replace piston dome.

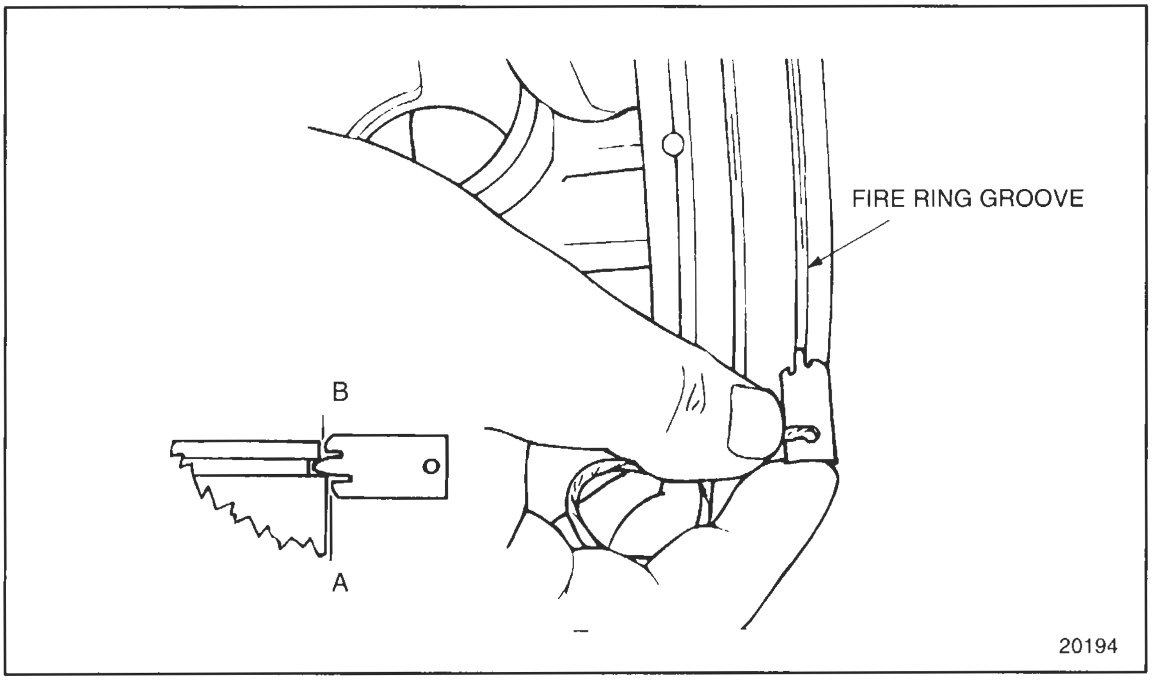


Figure 1–203 Checking Fire Ring Groove

3. Inspect tapered compression ring groove (second) in the piston dome.
   [a] Using piston ring land step gage, J 38689–A, check the groove.
   [b] If the compression ring groove is worn beyond usable limits, replace piston dome.
4. Inspect the piston pin.

NOTICE:
If piston pin is replaced for any reason, the piston pin bushing for that cylinder must also be replaced.

[a] Check the piston pin for fretting, cracking or signs of overhearing.

[b] If these are detected, replace piston pin.

[c] Measure piston pin outside diameter. Specifications are listed in Table 1–13.

[d] If piston pin is out of specs, replace with new part.

5. Inspect the piston pin bushings.

NOTICE:
If a piston pin bushing is replaced for any reason, the piston pin for that cylinder must also be replaced.

[a] Check the piston pin bushings for scoring, pitting, flaking, cracking, excessive wear, or signs of overheating.

[b] If these conditions are present, the bearings must be replaced.

6. Inspect the back of the upper bushing.

[a] Check the bushing for excessive fretting.

[b] If excessive fretting is evident, replace all three bushings.

[c] The corresponding fretting in the piston dome can be removed using crocus cloth, wet with fuel oil.

7. Inspect the edges of the bearings and piston dome pin bore.

[a] Check the edges of the bearing and piston dome pin bore for dents and dings.

[b] If any are found, it is acceptable to remove burrs at the bearings or pin bore edges by careful filing.

NOTE:
Remove any dirt or debris on the backs of the bearing or dome pin bore that may take up clearance required for bearing or piston pin installation.

8. Check the cylinder liner and block bore for excessive out-of-round, taper or high spots which could cause failure of the piston. Specifications are listed in Table 1-11.

9. Check the block bore for excessive out-of-round, taper, and high spots which could cause failure of the piston. Specifications are listed in Table 1-10.

1.17.4 Assembly of Piston and Piston Rings

Prior to installing the piston rings, the ring gap of each piston ring must be measured.

1. Insert the piston rings inside of the cylinder liner one at a time, using a piston dome (inserted upside down into the liner) to push the ring down. The piston dome should be inserted into the liner, to the same depth as the ring being positioned.
2. For the oil control ring, insert the piston dome down into the liner, until the oil control ring land is just into the liner. This will ensure that the rings are parallel with the top of the liner, and that they are positioned in the liner within the normal area of ring travel.
3. After the three rings have been positioned in the liner, measure the ring gap of the top ring with a feeler gauge. See Figure 1–204. Remove the ring from the liner after the measurement is complete.
4. Repeat this procedure for each ring, and record your measurements. Allowable ring end gaps are listed in Table 1–3.

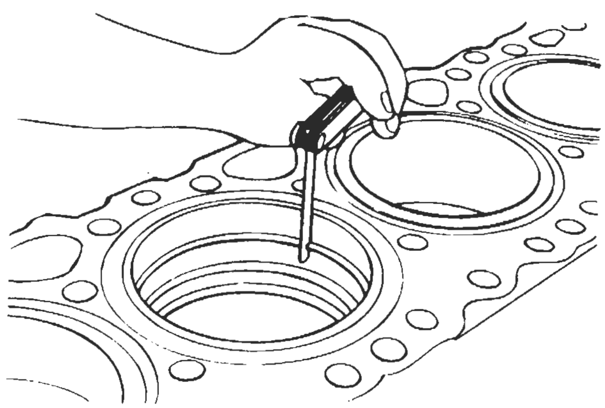


Figure 1–204 Piston Ring Location

Ring	Ring End Gap
Fire Ring (2.5 mm [.098 in.] chrome)	0.40–0.87 mm (.016–.034 in.)
Fire Ring (3.5 mm [.138 in.] plasma)	0.51–0.87 mm (.020–.034 in.)
Compression Ring	0.81–1.31 mm (.032–.051 in.)
Oil Control Ring	0.40–0.81 mm (.016–.032 in.)

Table 1–3 Allowable Ring End Gap

Assemble the piston and piston rings as follows:

1. Install the ring expander in the oil control ring groove in the piston. See Figure 1-205.

NOTE:
Install expander into inside diameter groove of ring with expander spring gap located 180° from the oil control ring gap.

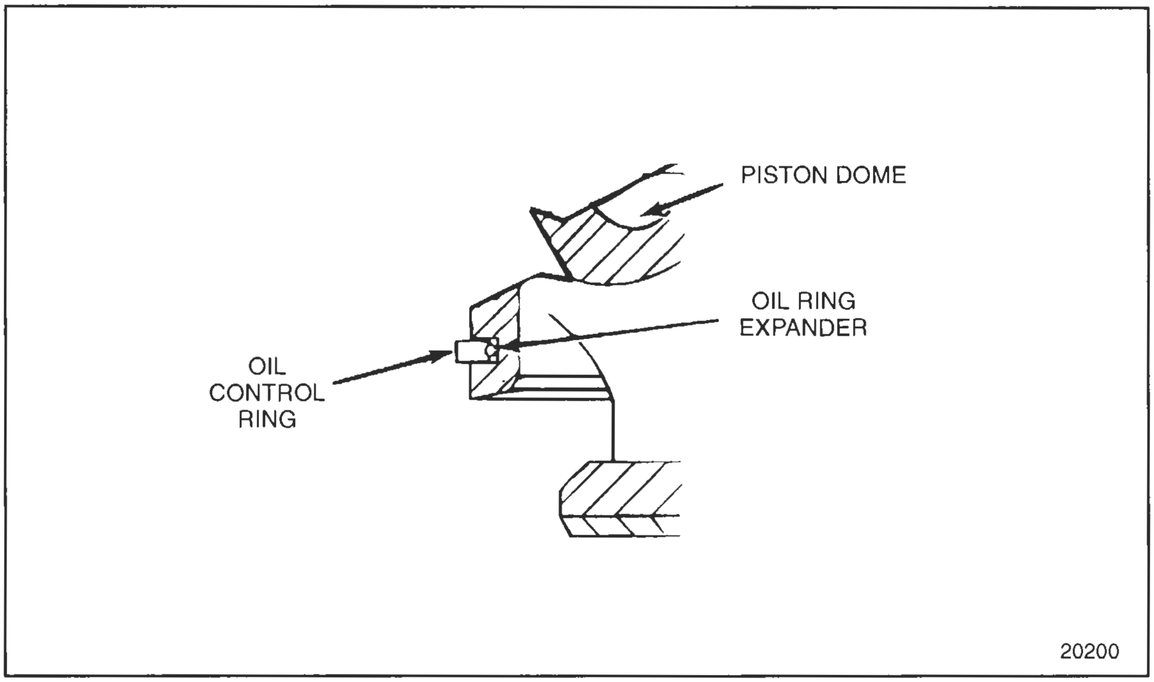


Figure 1–205 Piston Ring Installation

2. Install the oil control ring by hand. See Figure 1-206.

NOTE:
The oil control ring may be installed in either direction.

Figure 1-206 Oil Control Ring Installation

The oil control ring expander has a white paint stripe. Make sure the paint mark can be seen after the oil control ring is installed at ring gap.

Install the fire and compression rings as follows:

NOTICE:
To avoid breaking or overstressing the rings, do not spread them any more than necessary to slip them over the piston dome.

1. Starting with the compression ring (second groove), install the compression ring and fire ring with tool J 22405-02. See Figure 1-207. Make sure the identifying dimple on the rings is installed up, toward the dome of the piston. See Figure 1-198 for ring identification and locations.

2. Stagger the ring gaps around the piston. See Figure 1–207.

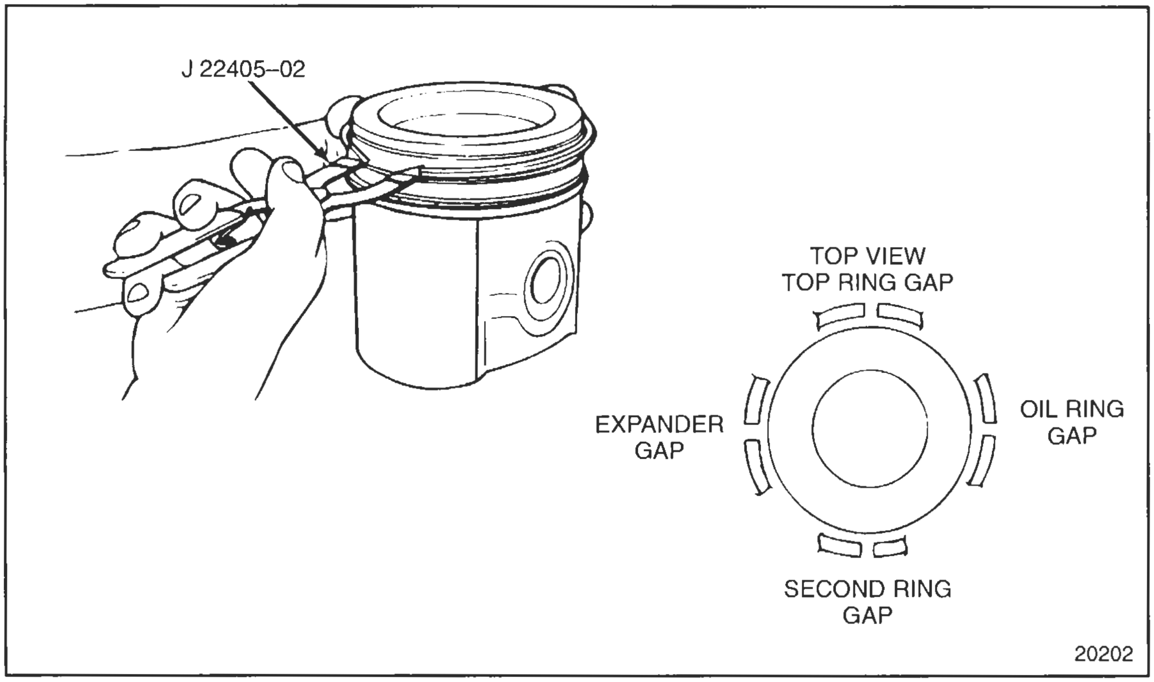


Figure 1–207 Piston Ring Positioning

3. Refer to section 1.18.4 for piston and connecting rod assembly procedure.

1.18 PISTON AND CONNECTING ROD ASSEMBLY

Since the piston and connecting rod assembly is one unit made of two separate components.

For general information, refer to section 1.17.

For connecting rod assembly information, refer to section 1.19.

1.18.1 Repair or Replacement of Piston and Connecting Rod

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1–208.

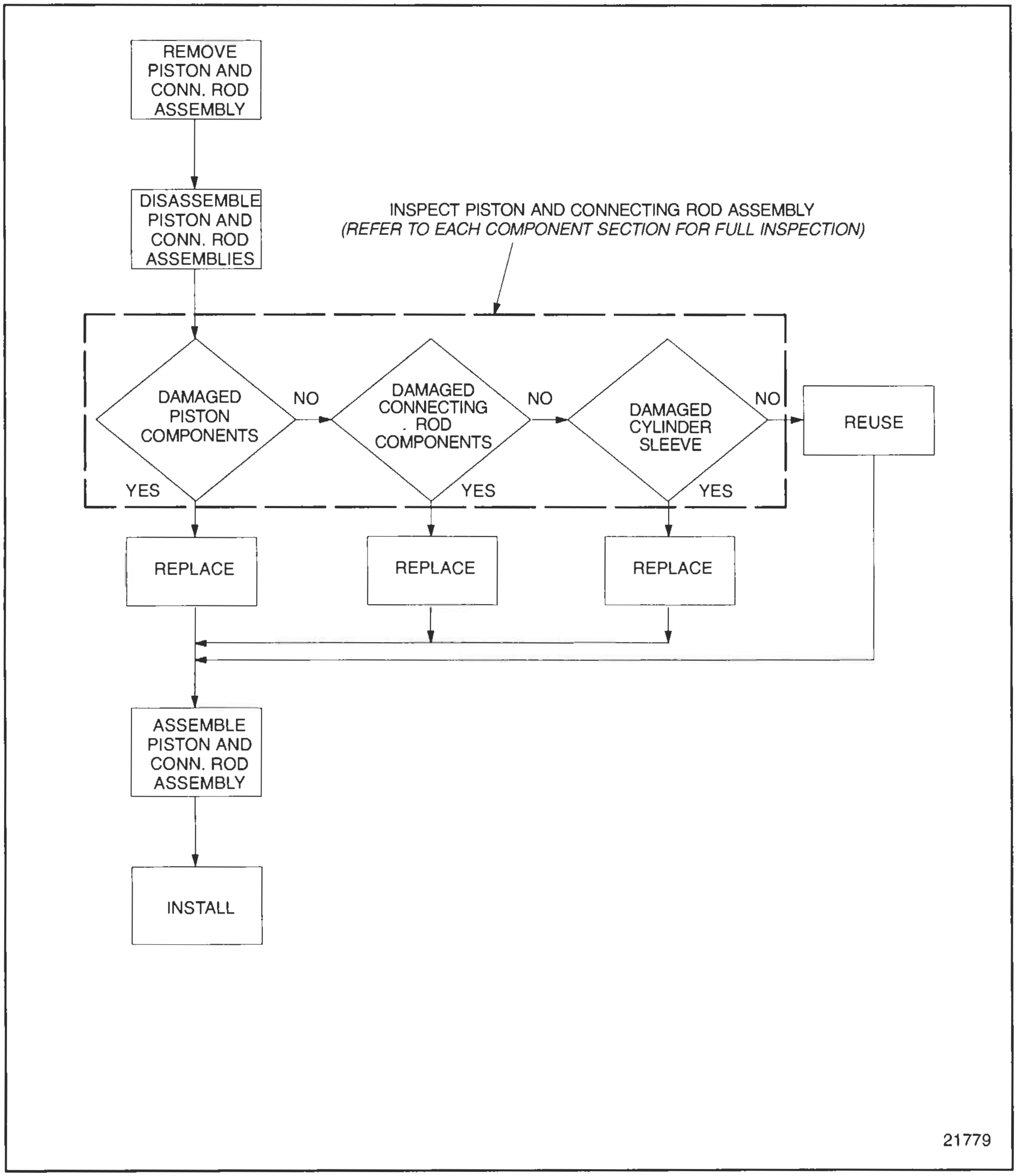


Figure 1–208 Flowchart for Repair or Replacement of Piston and Connecting Rod

1.18.2 Cleaning and Removal of Piston and Connecting Rod

Precleaning is not necessary.

Remove the piston and connecting rod assembly as follows:

1. Drain the engine cooling system. Refer to section 13.5.4.
2. Drain the engine oil and remove the oil pan. Refer to section 3.9.2.
3. Remove the cylinder head. Refer to section 1.2.2.
4. Use an emery cloth to remove any carbon deposits from the upper surface of the cylinder liner.
5. Remove the bearing cap and lower bearing shell from the connecting rod.
6. Install connecting rod guides, J 35945 (or equivalent), to protect the crankshaft journals.
7. Push the piston and rod assembly out through the top of the cylinder block.

NOTE:
The piston cannot be removed from the bottom of the cylinder block.

8. Assemble the bearing cap and lower bearing shell to the connecting rod after removal. If not already marked, match-mark the rod and cap (on the tang side) with the cylinder No. they were removed from. See Figure 1-209.

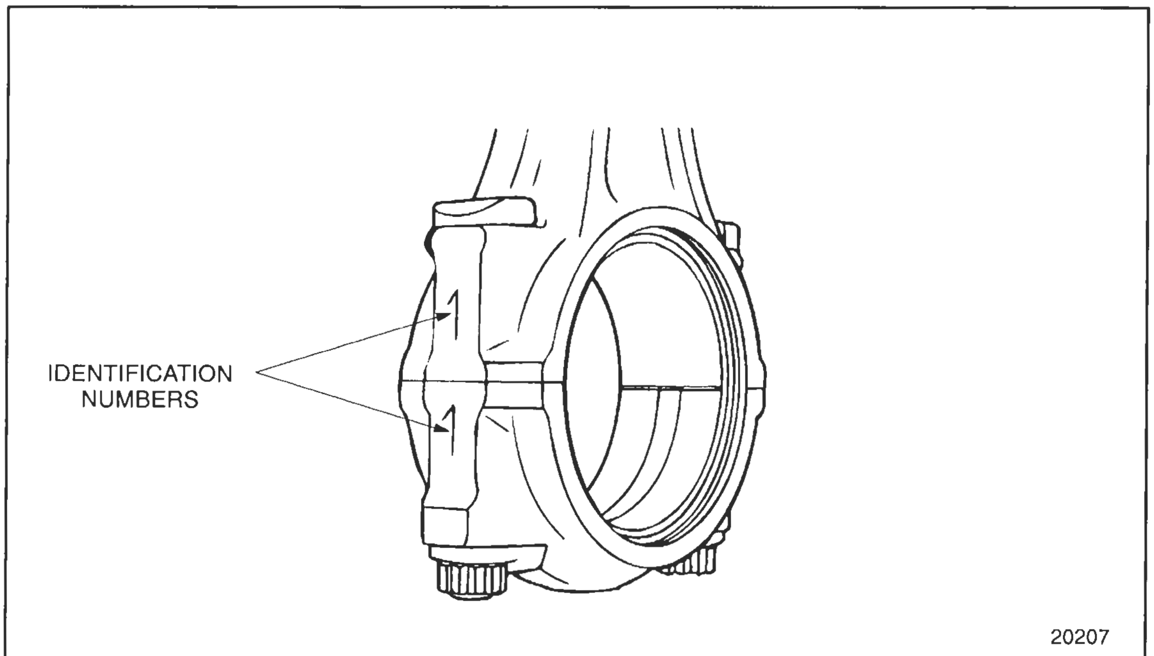


Figure 1–209 Connecting Rod and Cap Identification

NOTE:
When removed, the bearing cap and the bearing shell must be reinstalled on the original connecting rod before another connecting rod bearing cap is removed.

NOTE:
If removing the piston and connecting rod assembly to work on the cylinder liner, stop here. Refer to section 1.20.2 for cylinder liner removal procedure.

1.18.3 Disassembly of Piston and Connecting Rod Assembly

Piston assembly components should be segregated by cylinder and match-marked during disassembly to ensure they are assembled in the same position and orientation.

NOTICE:
Stamping cylinder numbers would damage the components.

It is best to use a paint pencil. Mark the pin, skirt, bushing, and dome ear at the front.

Disassemble the piston and connecting rod assembly as follows:

1. Place the piston, dome down, on the round plate of the piston and connecting rod holding fixture, J 36211. See Figure 1–210.

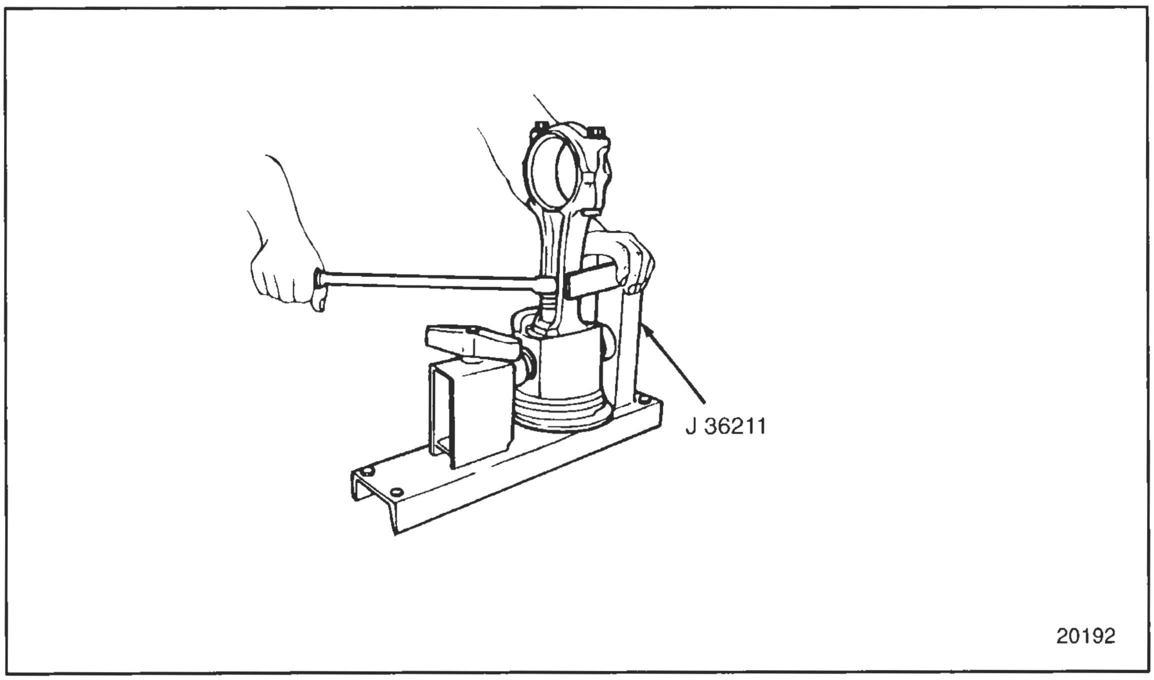


Figure 1–210 Piston Connecting Rod Holding Fixture

2. Slide the movable portion of the fixture until it contacts the piston pin and tighten the handle.

3. Loosen the two bolts that secure the connecting rod to the piston pin and remove the two bolts and spacers.
4. Remove the connecting rod.
5. Remove the piston, pin and skirt from the holding fixture.

1.18.3.1 Inspection of the Piston and Connecting Rod Assembly

Refer to section 1.17.3 for disassembly and inspection of the piston and piston rings.

Refer to section 1.19.3 for disassembly and inspection of the connecting rod.

1.18.4 Assembly of the Piston and Connecting Rod Assembly

Assemble the piston and connecting rod assembly as follows:

NOTICE:
The connecting rod–to–piston pin attaching bolts and spacers are specially designed components. No other bolts or spacers may be used. Piston pin bolts are considered one–use items and **must** be replaced with new bolts when removed for any reason. Failure to observe this precaution may result in bolt loosening or breaking during engine operation, which may cause serious engine damage.

1. Discard used piston pin bolts and replace with new bolts.
2. For specifications on reusing piston assembly components. Refer to section 1.18. Because of the low clearance fit between the piston pin and three–piece pin bearing, care in handling and cleanliness of piston dome bore, bearings and, piston pin are important. Otherwise, assembly may be impossible.
3. The pin bore and bearing backs should be wiped clean prior to installation of the bushings in the piston dome.
4. Installing piston pin bearings (with the piston dome standing on the rim) requires the upper bearing piece to be inserted through the end of the pin bore and dropped over the retaining pin.
5. The lower bearing pieces are inserted flat side in by tilting the bearing at approximately a 30° angle from the vertical away from the dome ear.
6. Set the edge of the bearing parting line on the edge of the upper piece notch and rotate the lower bushing up and into place.

7. The lower bearing can then be pushed full into the bore with the thumb. See Figure 1-211.

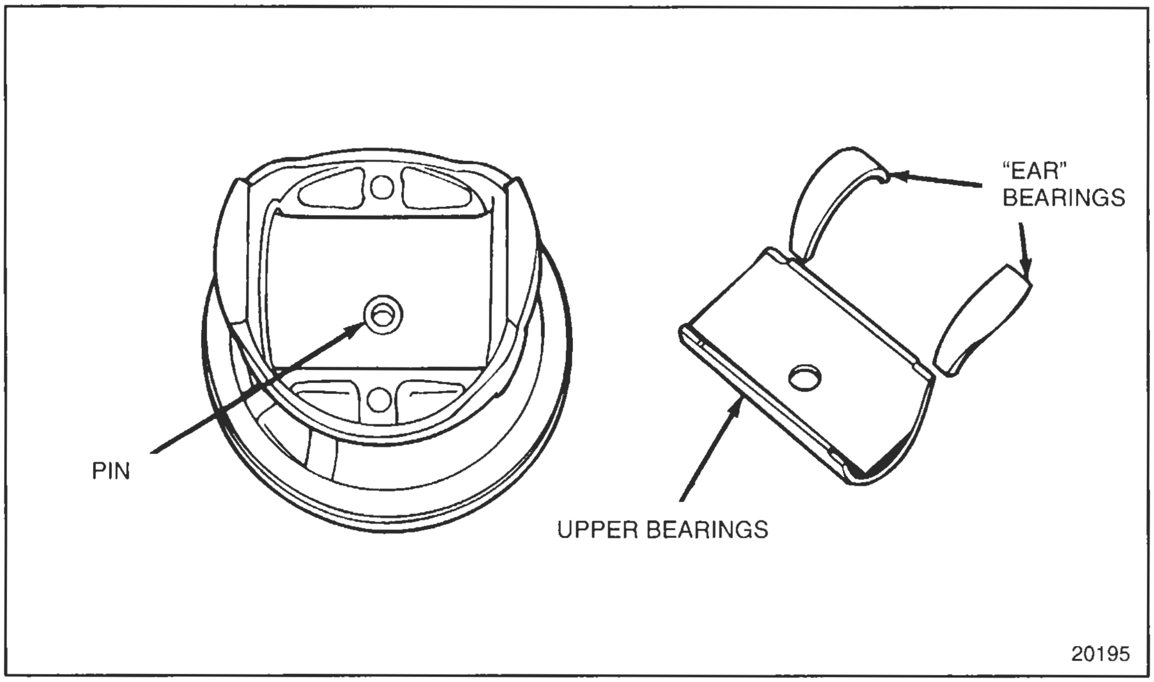


Figure 1–211 Piston Dome and Bearing Details

8. Lubricate the piston pin bearings with clean engine oil.
9. Set the piston skirt on the piston dome.
10. Align the piston pin holes in the dome and skirt.
11. Check the piston pin for foreign matter in the bolt holes.
12. Lubricate the pin with clean engine oil and install in the bores with the bolt holes facing the connecting rod, away from the dome.

NOTE:
The piston pin may feel considerably tighter than with conventional designs and possibly may not be turned easily by hand. Proper pin and bearing installation should result in a piston assembly in which the pin can be turned with the connecting rod while the piston dome is standing on the rim and the piston skirt is held with the other hand.

13. Apply a small amount of International Compound No. 2, or equivalent, to the bolt threads and bolt head contact surfaces and both ends of the spacers.

NOTICE:
The connecting rod–to–piston pin attaching bolts and spacers are specially designed components. No other bolts or spacers may be used. Piston pin bolts are considered one–time use items and must be replaced with new bolts when removed for any reason. Failure to observe this precaution may result in bolt loosening or breakage during engine operation, which may cause serious engine damage.

14. Install the spacers on the two special connecting rod–to–piston attaching bolts.
15. After clamping the connecting rod in holding fixture, J 36211, tighten each piston pin bolt to 95–122 N·m (70–90 lb·ft) torque.
16. Complete the process by tightening the bolts to 157 ±6.8 N·m (115 ±5 lb·ft) final torque.

1.18.5 Installation of Piston and Connecting Rod Assembly

Use piston ring compression tool, J 35598, to install the piston and connecting rod assembly to the engine as follows:

NOTICE:
Inspect the piston ring compressor for nicks or burrs, especially at the non–tapered inside diameter end. Nicks or burrs on the inside diameter of the ring compressor may result in damage to the piston rings.

1. Add clean engine oil to a clean drain pan at least 305 mm (12 in.) in diameter, until the level reaches approximately 76 mm (3 in.).
2. Place the piston and connecting rod assembly into the pan, with the dome of the piston on the bottom of the pan.

3. Coat the piston liberally with the engine oil, saturating the piston rings and lands. See Figure 1–212.

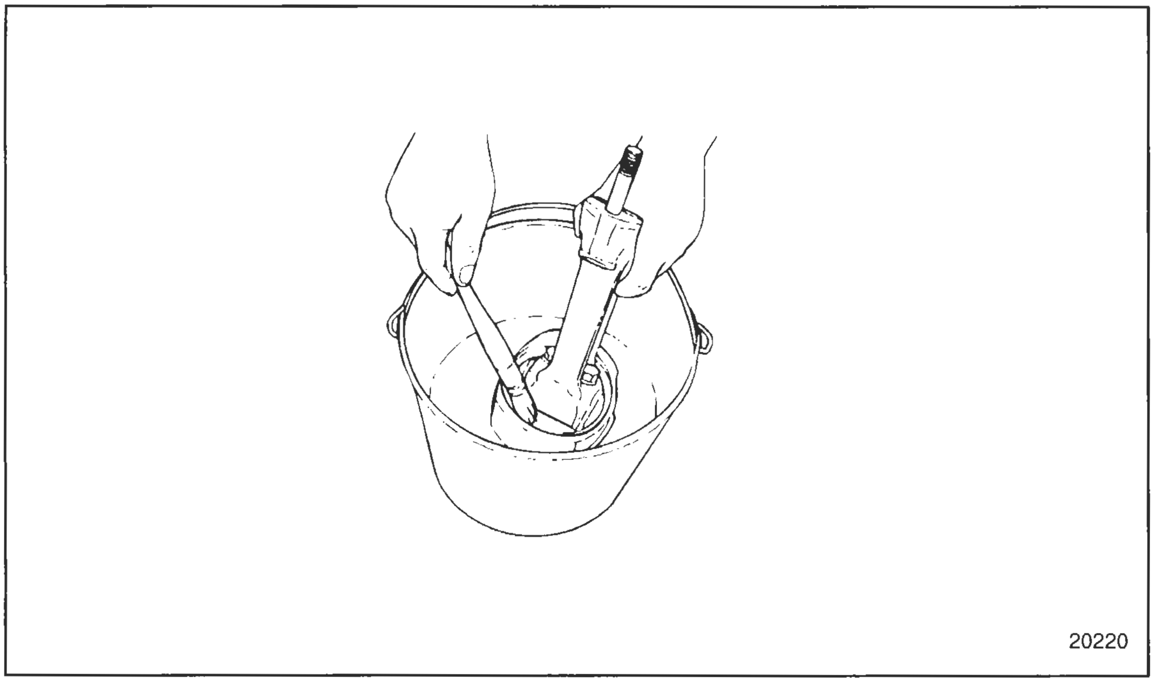


Figure 1–212 Piston and Connecting Rod Assembly Lubrication

4. Position (stagger) the piston ring gaps properly on the piston at 90° intervals. See Figure 1–213.

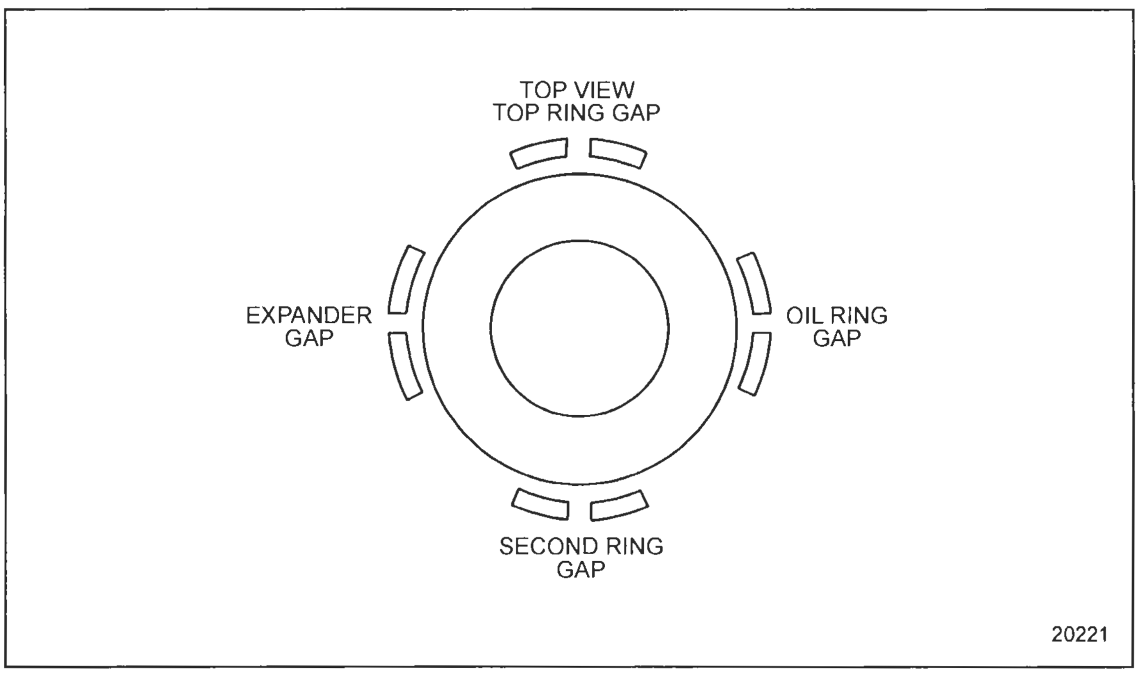


Figure 1–213 Piston Ring Positioning

5. Place the piston, dome down, in the bottom of the pan. Center the dome of the piston. See Figure 1–214.

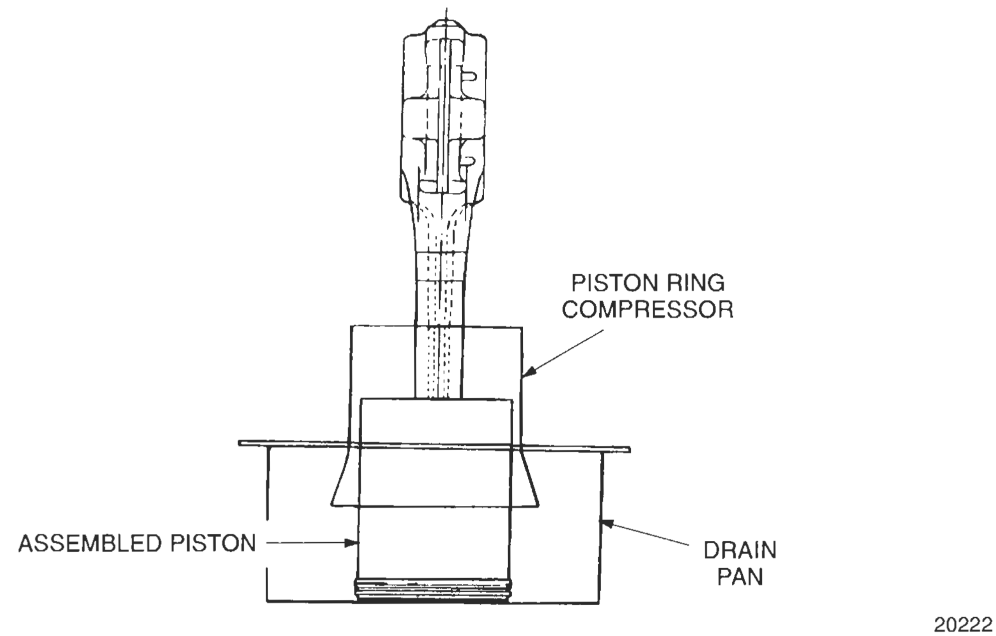


Figure 1–214 Installing Piston and Connecting Rod Assembly into Ring Compressor

6. Coat the inside diameter of the ring compressor liberally with clean engine oil from the pan.
7. Install the tapered end of the piston ring compressor over the end of the connecting rod, and down onto the piston. As the ring compressor slides down the piston to the piston ring area, apply slow, even pressure on both sides of the ring compressor to compress the rings.
8. Slide the ring compressor down until it contacts the bottom of the drain pan.
9. Position the crankshaft so that the connecting rod journal for the cylinder being worked on is at bottom–dead–center.
10. Remove the cap from the connecting rod.

NOTICE:

Do not allow the connecting rod to contact the cylinder liner on installation, or damage to the liner may occur. The numbers on the side of the connecting rod and cap identify the rod with the cap and indicate the particular cylinder in which they are used. If a new service connecting rod is to be installed, the same identification numbers must be stamped in the same location (on the tang side of the rod and cap) as on the connecting rod that was replaced.

11. Install connecting rod guides, J 35945, over the ends of the connecting rod bolts to prevent damaging the crankshaft journals or the joint face of the rod. The guides also prevent the connecting rod from contacting the liner and damaging the surface. See Figure 1-215.

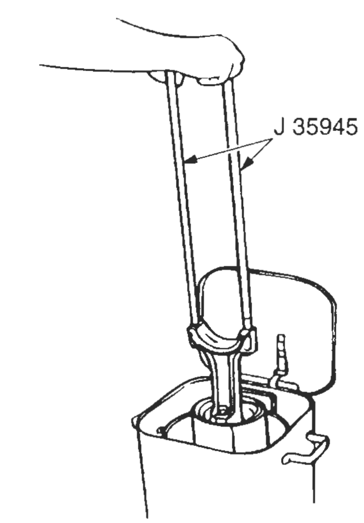


Figure 1–215 Connecting Rod Guides Installation

NOTE:
The connecting rod guides are threaded at the upper end and attach to the rod bolts.

12. Grasp the connecting rod assembly with one hand, and the piston ring compressor with the other. Lift the assembly out of the pan, and allow excess oil to drain back into the pan.

NOTE:
Do not allow the piston to slide out of the bottom of the ring compressor. DO NOT lift the assembly using the connecting rod guides.

13. With the crankshaft throw in the bottom position, place the ring compressor and the piston and connecting rod assembly over the cylinder it is to be installed in, being sure the No. on the connecting rod is towards the cooler side of the engine. See Figure 1–216.

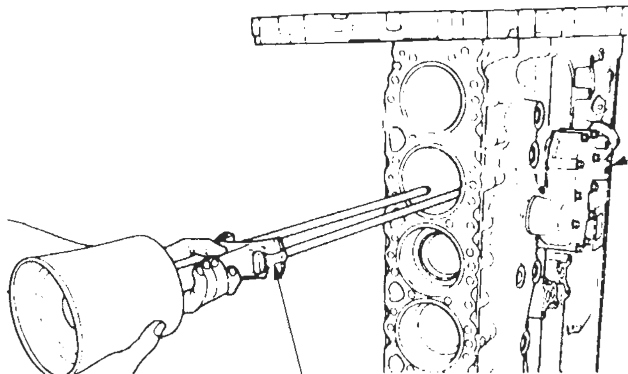


Figure 1–216 Connecting Rod Indexing

NOTE:
There are orientation lugs cast into one side of the upper and lower sections of the connecting rod. These orientation lugs face the front of the engine. See Figure 1–217.

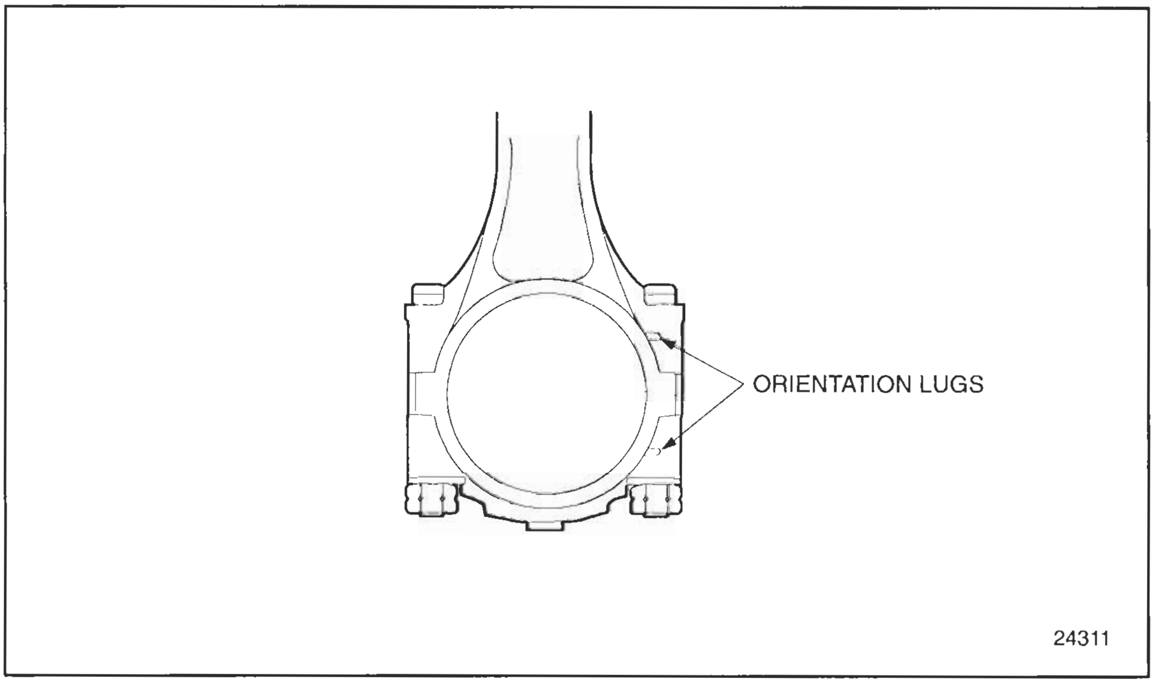


Figure 1–217 Orientation Lugs

14. Install the ring compressor, with piston and connecting rod inside, into the proper cylinder until the ring compressor is resting squarely on the cylinder liner. See Figure 1–218.

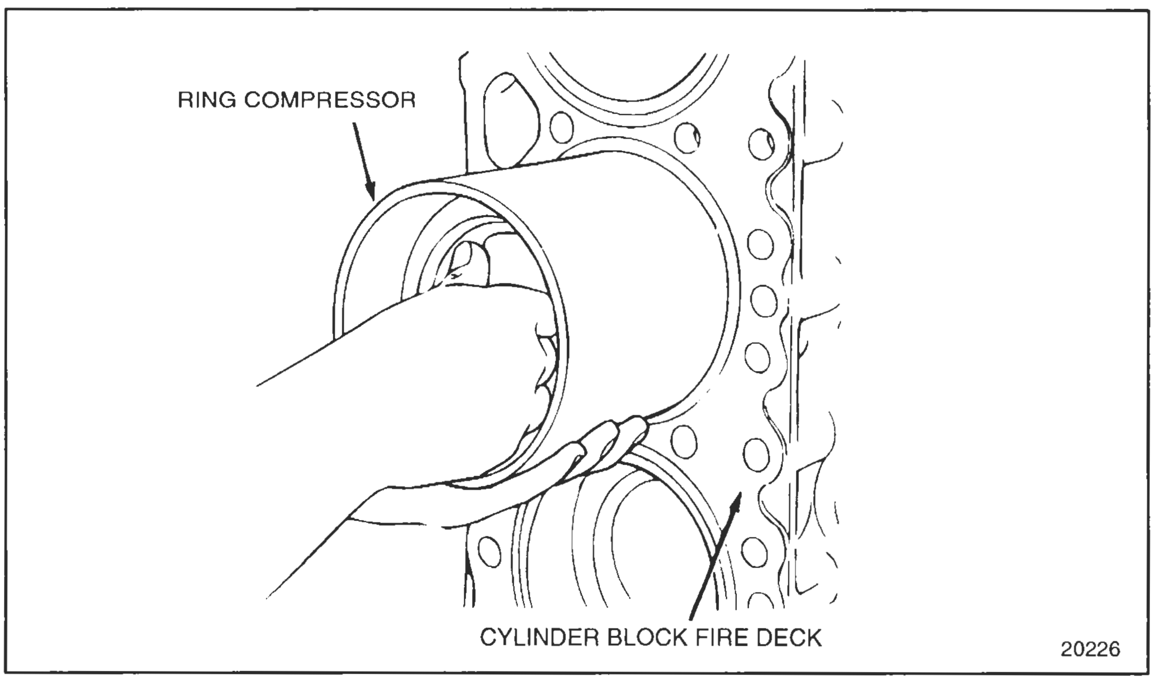


Figure 1–218 Use of Ring Compressor

NOTICE:
Do NOT force the piston into the liner. The oil ring expander applies considerable force on the oil ring. Therefore, care must be taken during the loading operation to prevent ring breakage.

15. Push the piston and connecting rod assembly down into the liner until the piston is free of the ring compressor.
16. Remove the piston ring compressor.
17. Push or tap the piston and connecting rod assembly into the liner until the upper bearing shell is firmly seated on the appropriate crankshaft journal.
18. Remove the protective sleeves from the ends of the connecting rod bolts.

NOTE:
Be sure the connecting rod bolts have not been unseated or turned and the bearing locating tang is in its proper location.

19. Place the lower bearing shell in the connecting rod cap, indexing the tang on the bearing with the notch in the cap.
20. Lubricate the bearing shell with clean engine oil.
21. Install the bearing cap. The No. on the cap and rod should be on the same (oil cooler) side. See Figure 1–219.

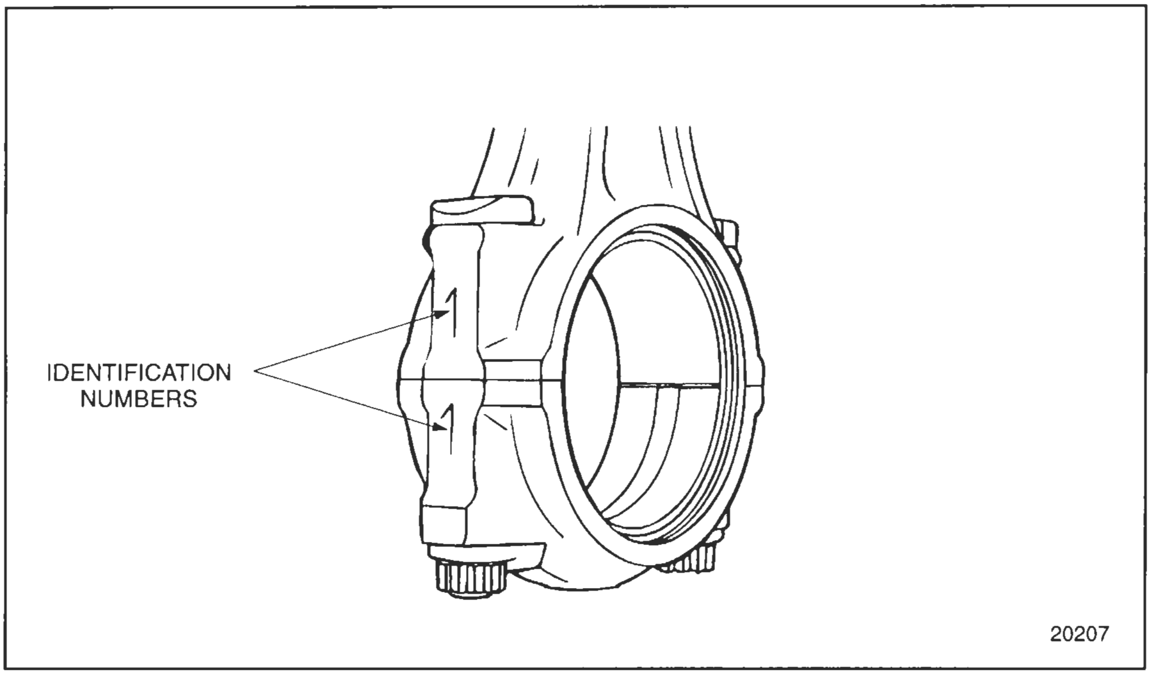


Figure 1–219 Connecting Rod and Cap Identification

22. Tighten the connecting rod bolts alternately to 160–185 N·m (118–137 lb·ft) torque.
23. Check connecting rod side clearance by moving the rod from crank cheek–to–crank cheek. If there is no clearance, check bearing cap installation.
24. Install the remaining piston and rod assemblies in the same manner.
25. Install a new head gasket. Refer to section 1.2.5.
26. Install the cylinder head. Refer to section 1.2.5.
27. Install the lubricating oil pump and balance shaft assembly inlet pipe and screen assembly, and the lubricating oil pump. Refer to section 3.2.5
28. Install the oil pan. Refer to section 3.9.3.
29. Complete any other engine assembly as necessary.
30. After the engine has been completely assembled, refill the crankcase to the proper level on the dipstick. Refer to section 13.5.1.
31. Close the drain cocks and fill the engine with the recommended coolant. Refer to section 13.5.4.

NOTE:
Coolant system maintenance is very important. Bleed off all of the air from the system and top off.

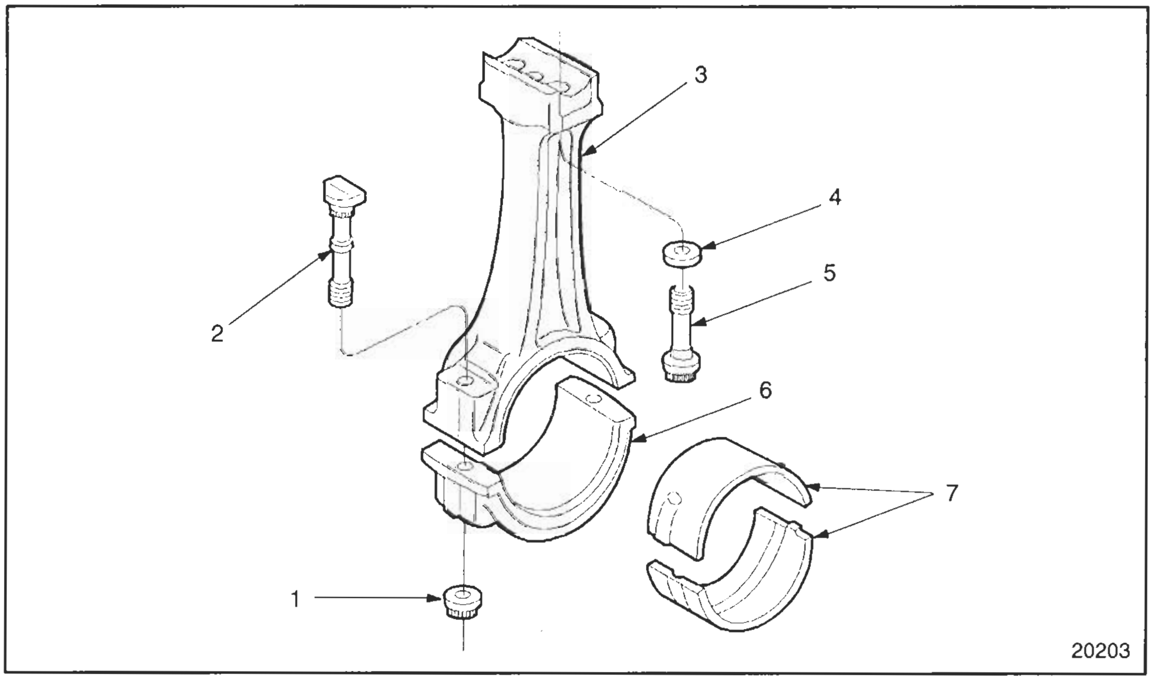
32. If new parts such as pistons, rings, cylinder liners or bearings were installed, operate the engine on the run–in schedule. Refer to section 11.6.2.
33. Refer to section 11 for verification of proper piston and connecting rod assembly installation.

1.19 CONNECTING ROD

The connecting rod is forged to an "I" section with an open or saddle type contour at the upper end and a bearing cap at the lower end. The surface of the connecting rod is shotpeened for added strength. Therefore, no grinding is permitted since it will remove the benefits of shot-peening. See Figure 1-220.

The upper end of the connecting rod is machined to match the contour of the piston pin. The piston pin is secured to the connecting rod with two special bolts and spacers. The lower bearing cap is secured to the connecting rod by two specially machined bolts and nuts.

The two special bolts locate the cap relative to the upper end. The assembly is machined as a unit and must not be used in the engine with any other cap or upper end. Orientation of the cap to the upper end is identified by stamped numbers.



1. Rod Bolt Nut
2. Connecting Rod Cap Bolt (2)
3. Connecting Rod
4. Spacer
5. Piston Pin Bolt (2)
6. Connecting Rod Bearing Cap
7. Bearing Shells

Figure 1–220 Connecting Rod and Bearing Shells

The connecting rods replaced the former connecting rods, effective with the following engine serial numbers:

ENGINE MODEL	ENGINE SERIAL No.
All Series 50 Engines	4R6665

Table 1–4 New Connecting Rod Replacement

This change was made to allow installation of new, wider connecting rod bearings that provide improved oil film thickness and reduced bearing pressures.

The rod chamfers on the new connecting rods are smaller than those on the former rods. This has been done to provide proper support for the wider bearings. To conform with this change, new crankshafts with smaller fillet radii have been released. Refer to section 1.7 for information of the new crankshafts.

NOTE:
The new connecting rods, bearings, and crankshafts *must* be used together to ensure interchangeability. Former parts cannot be mixed with new parts in the same engine. The former connecting rods will continue to be available for engines built prior to the unit serial numbers as listed in Table 1–4.

The connecting rod bearing shells are precision made and are of the replaceable type. The upper bearing shell is seated in the connecting rod and a lower bearing shell is seated in the connecting rod cap. These bearings are not identical. The upper and lower bearing shells are located in the connecting rod by a tang at the parting line at one end of each bearing shell. See Figure 1-220.

The tri-metal bearing wear surfaces use a steel backing. First, an optimum composition (copper, tin and lead) lining is bonded to the steel back. A nickel barrier above the lining and the overlay serves to prevent tin migration. A soft lead overlay, 0.025 mm (.001 in.) thick, provides run-in protection, and an initial wear surface. A flash tin plate, front and back, is for added corrosion protection and resistance during shipping and handling. These bearings are identified by the satin silver sheen of the tin when new and a dull gray of the overlay after being in service.

The oil hole through the upper bearing shell supplies oil to the oil passage in the connecting rod, thereby providing a supply of lubricating oil from the crankshaft to the connecting rod bearings, piston-pin bushing, and underside of the piston dome. The upper shell is grooved from one edge to the oil hole. The lower shell has a full-length (180°) groove. See Figure 1-221.

The connecting rods bearing caps are numbered according to the cylinder position with matching numbers stamped on the connecting rod tang side.

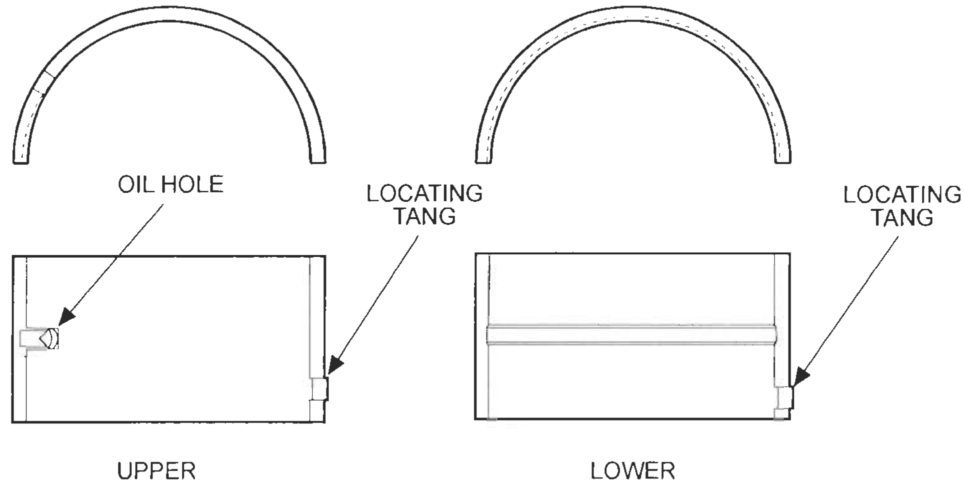


Figure 1–221 Connecting Rod Bearing Detail

New, wider connecting rod bearings replaced the former connecting rod bearings as listed in Table 1–4.

This change was made to improve oil film thickness and reduce bearing pressures. The new bearings are 47.44–47.14 mm (1.868–1.856 in.) wide. The former bearings were 43.44–43.14 mm (1.710–1.698 in.) wide. To provide full support for the wider bearings, new connecting rods with smaller rod chamfers and new crankshafts with smaller fillet radii were also released. Refer to section 1.7 for information on the new crankshafts.

NOTE:
The new connecting rod bearings, connecting rods, and crankshafts *must* be used together to ensure interchangeability. Former parts cannot be mixed with new parts in the same engine. The former bearing shells will be available for engines built prior to the unit serial numbers as listed in Table 1–4.

1.19.1 Repair or Replacement of Connecting Rod

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1–222.

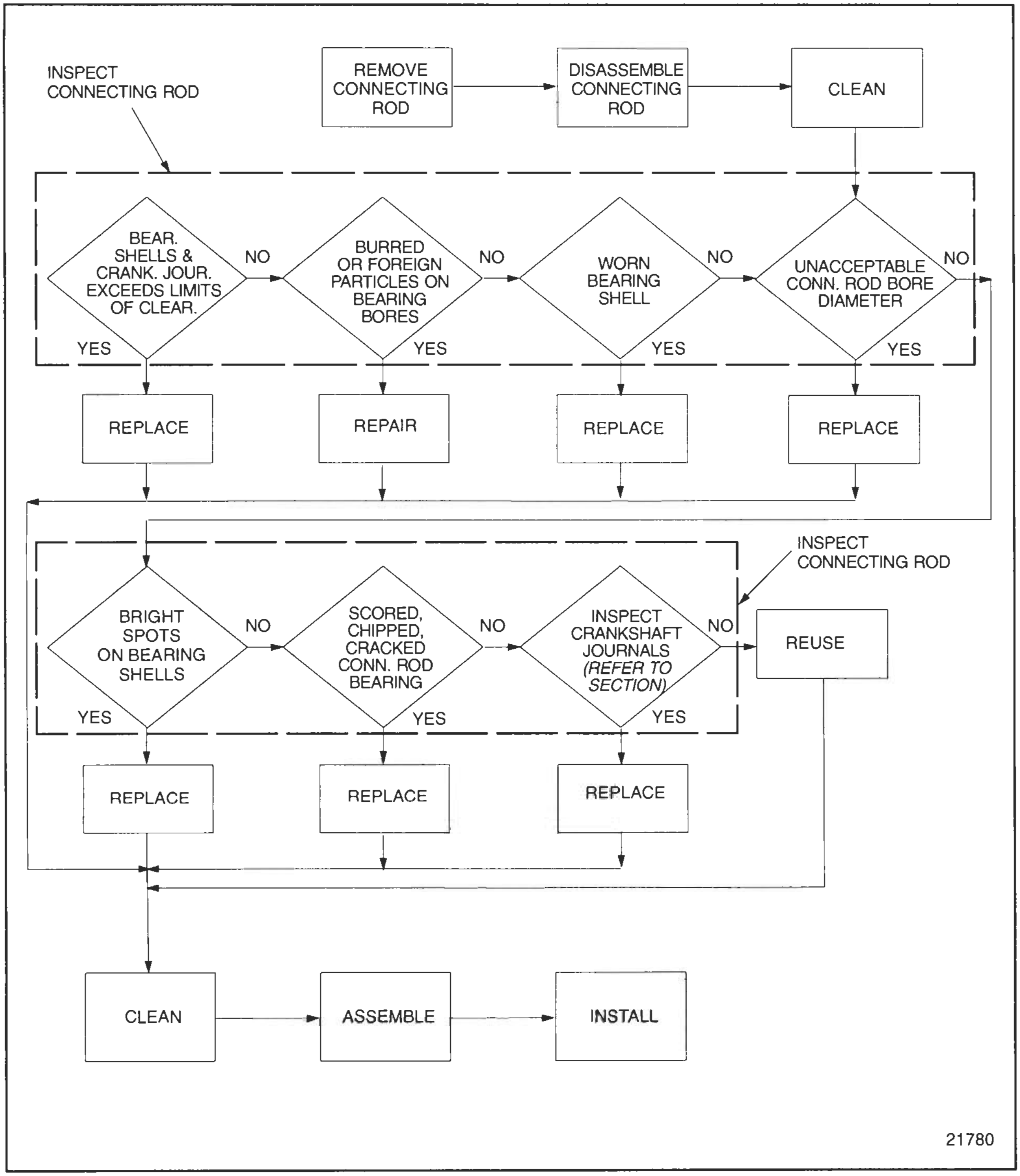


Figure 1–222 Flowchart for Repair or Replacement of Connecting Rod

1.19.2 Cleaning and Removal of the Connecting Rod

Before removal, make sure the connecting rods and caps are stamped with their correct cylinder location. If not marked, stamp location (1–4) on the tang side (cooler side) of the rod and cap.

Refer to section 1.18.2 for piston and connecting rod assembly removal procedure.

1.19.3 Disassembly of Connecting Rod

Disassemble the connecting rod as follows:

NOTE:
It is best to disassemble, inspect and assemble each connecting rod separately. It's very important to keep the connecting rod cap, and the upper and lower bearing shells to the original connecting rod.

1. Loosen and remove the two bolts.
2. Remove connecting rod cap and bearings shells.

1.19.3.1 Inspection of Connecting Rod

Clean the bearings prior to inspection as follows:

1. Clean the bearings with fuel oil.

CAUTION:
To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

2. Dry the bearings with compressed air.

Inspect the connecting rod as follows:

1. Inspect the connecting rod saddle at the piston pin contact surface for traces of fretting and corrosion.
2. To repair, wet with fuel oil and smooth with crocus cloth.

1.19.4 Assembly of Connecting Rod

Assemble connecting rod as follows:

1. Install the connecting rod cap with the numbers on the same (oil cooler) side on the connecting rod.
2. Lubricate the bolt threads with clean engine oil.

NOTICE:
Be sure the connecting rod bolt has not turned in the connected rod before torque is applied to the nut.

NOTICE:
Do not over torque the connecting rod bolt nuts. Over torque may permanently distort the connecting rod cap.

3. Tighten the bolt nuts to 160–185 N·m (118–137 lb·ft) torque.

1.19.4.1 Inspection of Assembled Connecting Rod

Measure the connecting rod bearing diameter at five locations. See Figure 1–223.

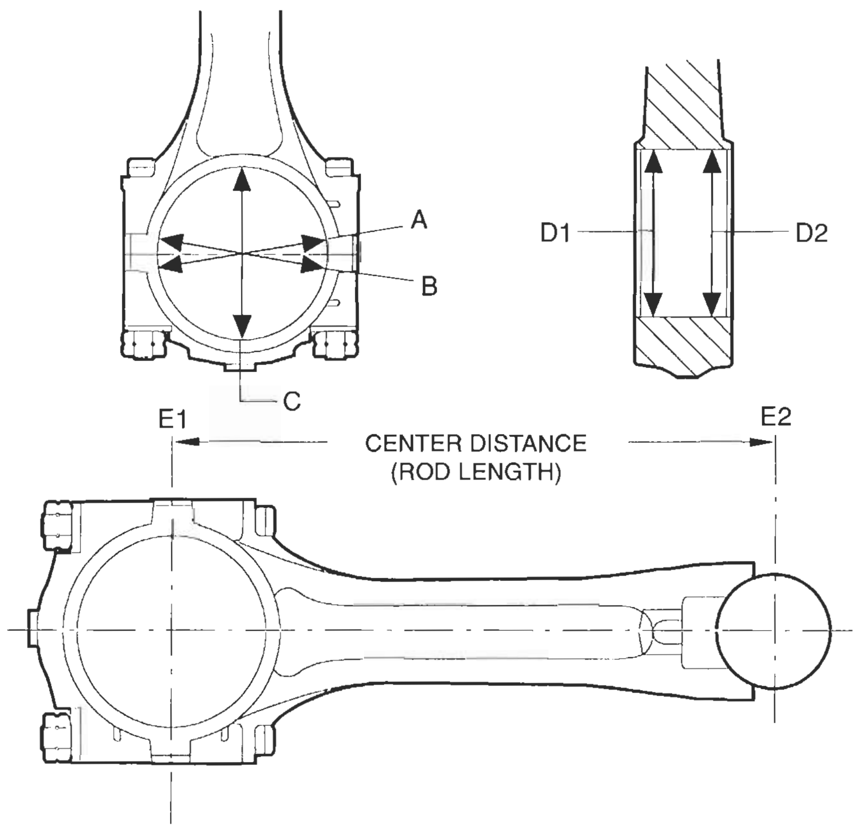


Figure 1–223 Dimensional Inspection of Cross–head Piston Connecting Rods

1. Calculate size of diameter at split line, W. [W=(A+B)÷2].
2. Calculate the average bore out-of-round, X. [X=W–C] X must be between –0.012 and 0.012 mm (–.0005 and .0005 in.).
3. Calculate the average connecting rod bearing bore size, Y. [Y=(W+X)÷2] Y must be between 91.288 and 91.313 mm (3.594 and 3.595 in.).
4. Determine taper, Z. [Z=D2–D1] Z must be between –0.012 and 0.012 mm (–.0005 and .0005 in.).

5. Determine the rod length by finding the distance between E1 and E2. See Figure 1-223.
   [a] The acceptable rod length specification for Series 50 Engines are: 269.25–269.35 mm (10.6004–10.6043 in.).
   [b] If the connecting rod bore is not to specifications, the rod must be scrapped and cannot be machined.
6. If a new service connecting rod is required, stamp the cylinder number on the connecting rod and cap. Refer to section 1.18.2.

1.19.4.2 Inspection of Connecting Rod Bearings and Bearing Bores

Inspect the connecting rod bearing as follows:

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

1. Clean the rust preventive from a service replacement connecting rod and blow compressed air through the drilled oil passage to be sure it is clean of obstructions. Also make sure the split line (cap to rod) is thoroughly cleaned.
2. Check connecting rod bearing wear surfaces for scoring, pitting, flaking, chipping, cracking, loss of overlay, or signs of overheating.
   [a] Overlay plated bearings may develop very small cracks or small isolated cavities ("checking") on the bearing surface during engine operation. These are characteristics of and are NOT detrimental to this type of bearing. The bearings should not be replaced for these minor surface imperfections. The upper bearing shells, which carry most of the load, will normally show signs of distress before the lower bearing shells do. If the overlay is worn through to the copper across the bearing shell, all the bearing shells must be replaced.
   [b] If any of these conditions are detected, replace the bearings.
3. Inspect the backs of the connecting rod bearing shells.
   [a] Check for bright spots that indicate shells have been shifting in their bores.
   [b] If bright spots are evident, replace the bearings shells.
4. Inspect the connecting rod bearing bores.
   [a] Check for burrs or foreign particles.
   [b] Use an emery cloth to smooth bore surface, otherwise replace part.

5. Inspect the bearings shells.
   [a] Measure the thickness of the bearing shells, using a micrometer and ball attachment, refer to section 1.9.2.1. The minimum thickness of a worn standard connecting rod bearing shell should not be less than 3.086 mm (.1215 in.).
   [b] If either bearing shell is thinner than this dimension, replace both bearing shells.
6. Inspect the bearing shells and the crankshaft journals.
   [a] Check the clearance between the connecting rod bearing shells and the crankshaft journals using a soft plastic measuring strip which is squeezed between the journal and the bearing. Refer to section 1.A and see Figure 1-374.
   [b] If the connecting rod bearing-to-journal clearance exceeds 0.151 mm (.006 in.) with used parts, replace with a new bearing.

NOTE:
Before installing the bearings, inspect the crankshaft journals. Refer to section 1.7. Do NOT replace one connecting rod bearing shell alone. If one bearing shell requires replacement, install both new upper and lower bearing shells. Also, if a new or reground crankshaft is to be used, install all new bearing shells.

NOTE:
Bearing shells are NOT reworkable from one undersize to another under any circumstances.

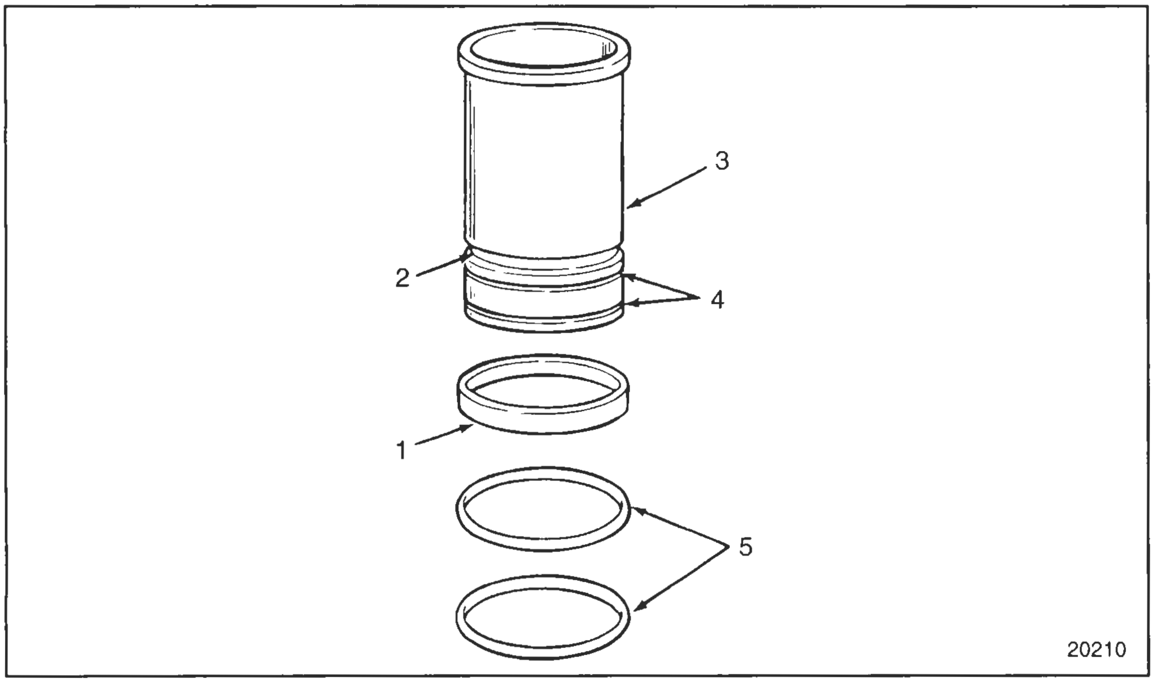
Bearing shells are available in 0.250, 0.500 and 0.750 mm (approximately .010, .020, and .030 in.) undersize for service with reground crankshafts. To determine the bearing size required, refer to section 1.A, and listed in Table 1-6.

1.19.5 Installation of Connecting Rod

Refer to section 1.18.5 to install the piston and connecting rod assembly.

1.20 CYLINDER LINER

The cylinder liner is of the replaceable wet type, made of hardened alloy cast iron, and is slip fit in the cylinder block. See Figure 1-224.

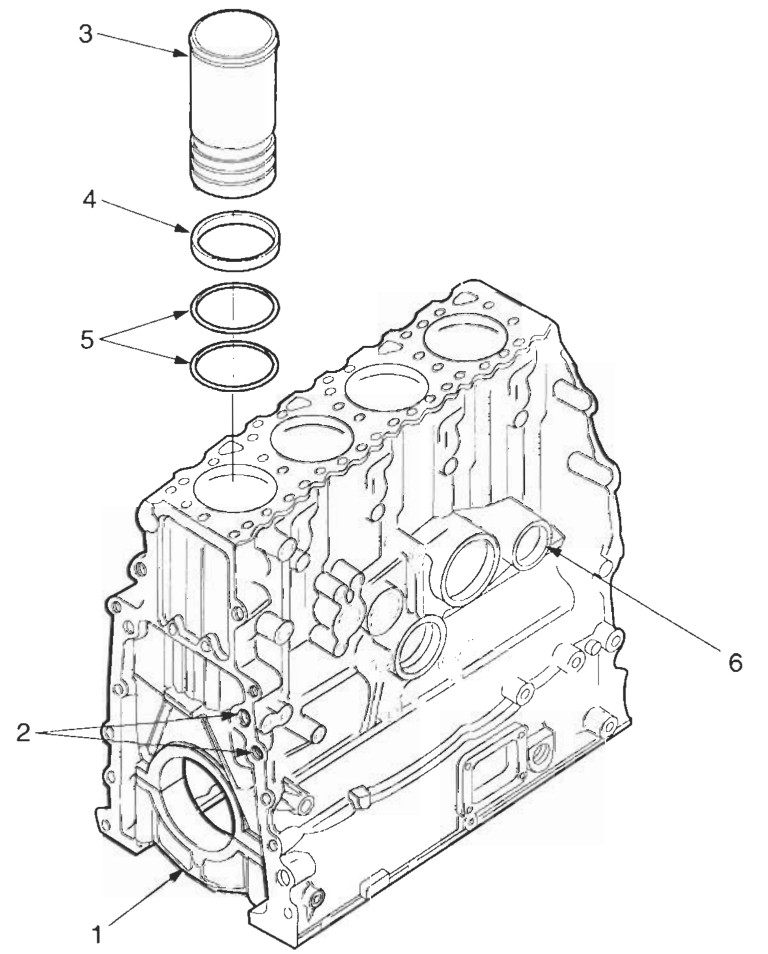


1. Crevice Seal
2. Crevice Seal Groove
3. Cylinder Liner
4. D-ring Grooves
5. D-ring Seals

Figure 1-224 Cylinder Liner and Related Parts

Coolant in the cylinder block water jacket surrounds the liner and cools it directly. A cooling channel is also cut into the liner immediately below the flange. Coolant flow through this channel and around the rest of the liner controls critical ring and liner temperatures for long cylinder component life.

The liner is inserted in the cylinder bore from the top of the cylinder block. The flange at the top of the liner fits into a counter bore in the cylinder block. See Figure 1–225.



1. Rear Main Bearing Cap
2. Oil Galleries
3. Cylinder Liner
4. Crevice Seal
5. D–Ring Seals
6. Integral Coolant Inlet Manifold

Figure 1–225 Cylinder Liner Installation

NOTICE:

The crevice seal prevents coolant from being pumped in and out of the area adjacent to the liner lower block location which could result in cavitation and corrosion damage to the liner and the block.

A crevice seal, fitting in the wide uppermost groove in the liner helps to stabilize the liner in the cylinder block bore.

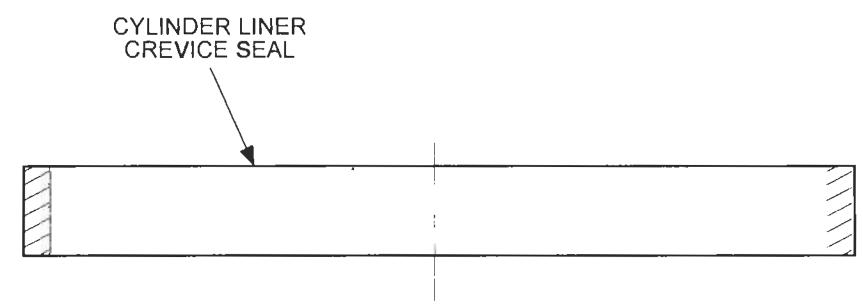


Figure 1–226 Cylinder Liner Crevice Seal Cross–section

This seal also keeps any debris that is in the cooling system from causing abrasion damage to the upper "D" liner seal ring. See Figure 1–226.

Two Teflon–coated, D–shaped seal rings, recessed in the lower two grooves in the cylinder liner, are used between the liner and the block to prevent coolant and oil leakage. See Figure 1–227.

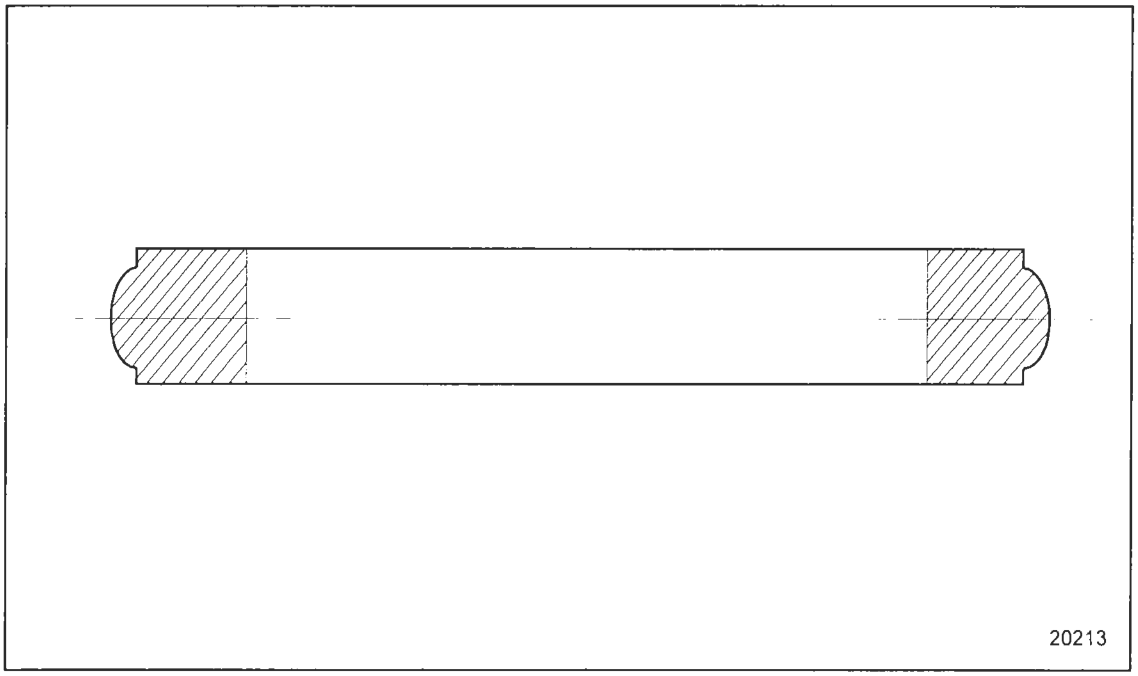


Figure 1–227 Cylinder Liner Seal Ring Cross–section

A weep hole for each cylinder is drilled through the cylinder block exterior, into the cylinder bore area. This weep hole is located between the two D–shaped seal rings. It is used to determine if engine coolant is leaking past the upper liner seal, or if oil is leaking past the lower liner seal. See Figure 1–228. A special rubber plug prevents dirt from getting into the "D" seal ring areas and causing abrasive damage. At the same time it allows leaking oil or coolant a path out of the engine for detection.

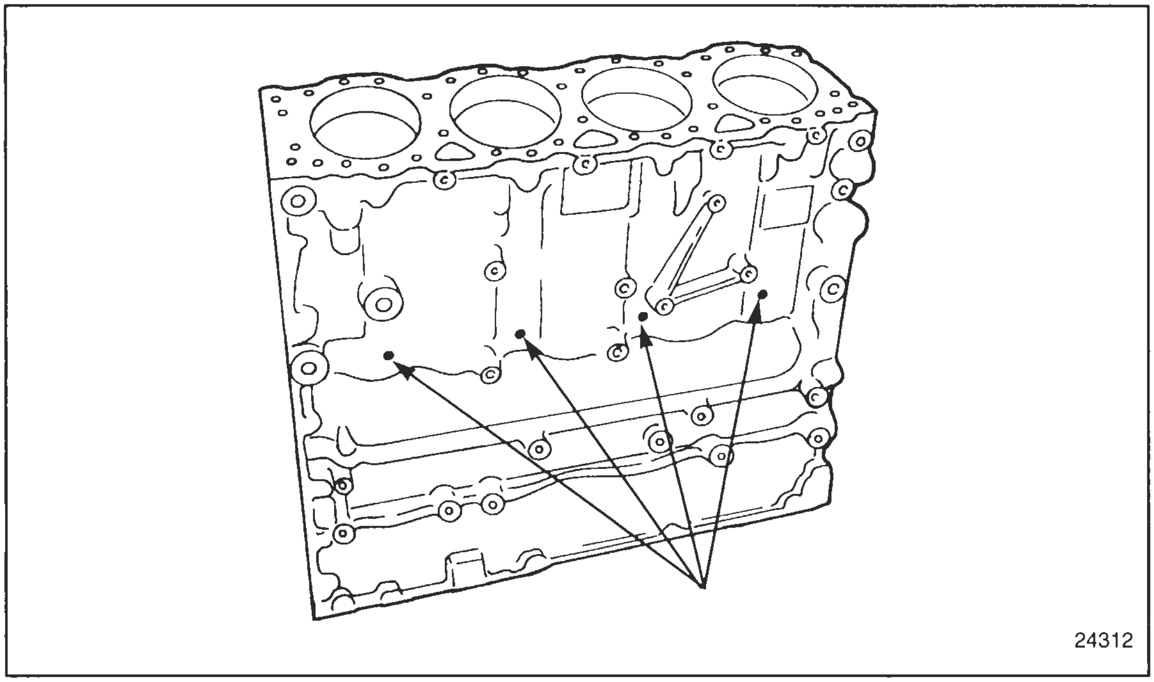


Figure 1–228 Weep Hole Plug Locations

1.20.1 Repair or Replacement of Cylinder Liner

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1–229.

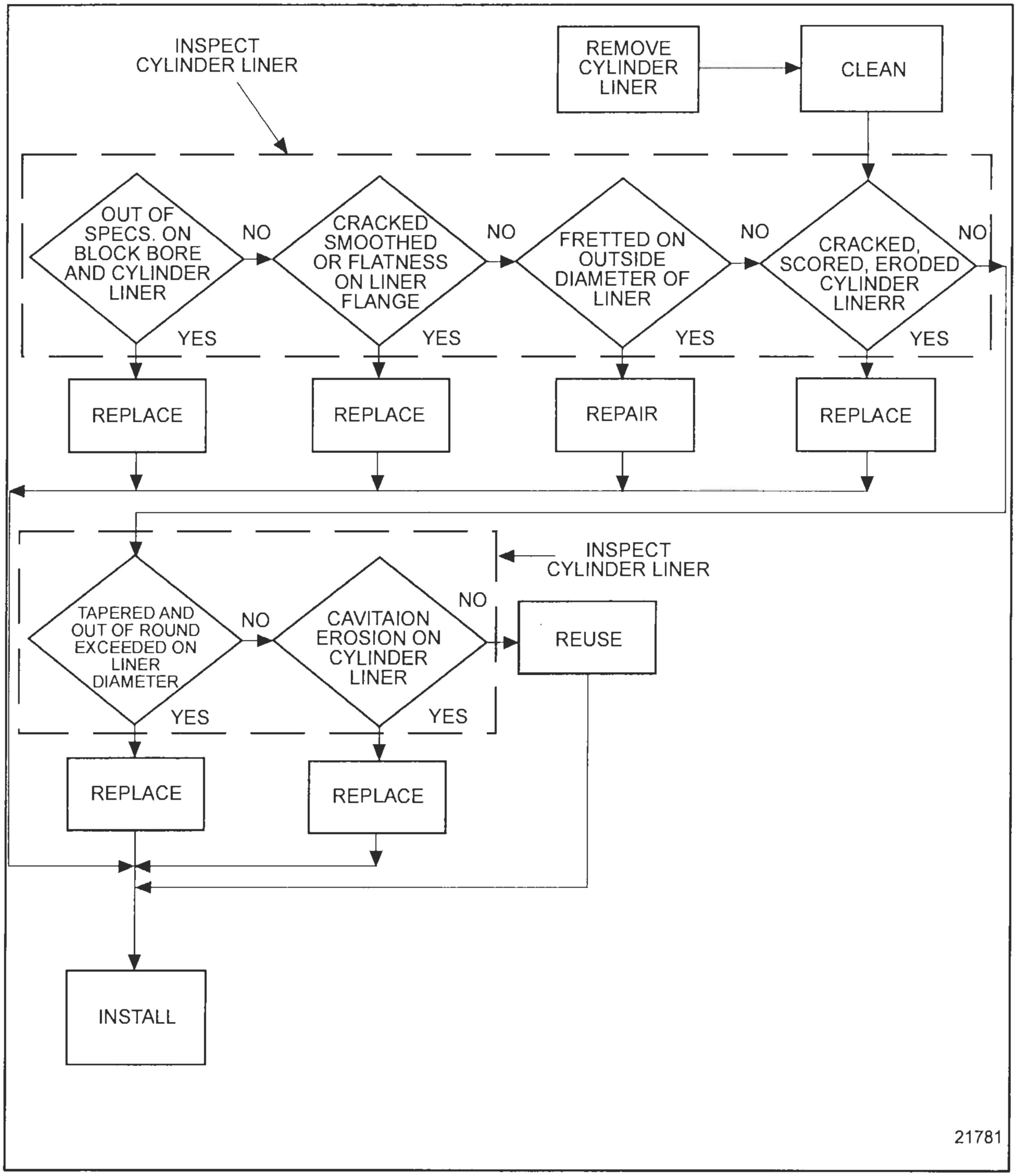


Figure 1–229 Flowchart for Repair or Replacement of Cylinder Liner

1.20.2 Cleaning and Removal of Cylinder Liner

Precleaning is not necessary.

NOTICE:
The proper method must be followed when removing a cylinder liner. Damage to the liner and the cylinder block may occur if the proper tools and procedures are not used.

1. Remove the piston and connecting rod as an assembly. Refer to section 1.18.2.
2. Remove the cylinder liner with cylinder liner remover, J 35791. See Figure 1–230 and see Figure 1–231.

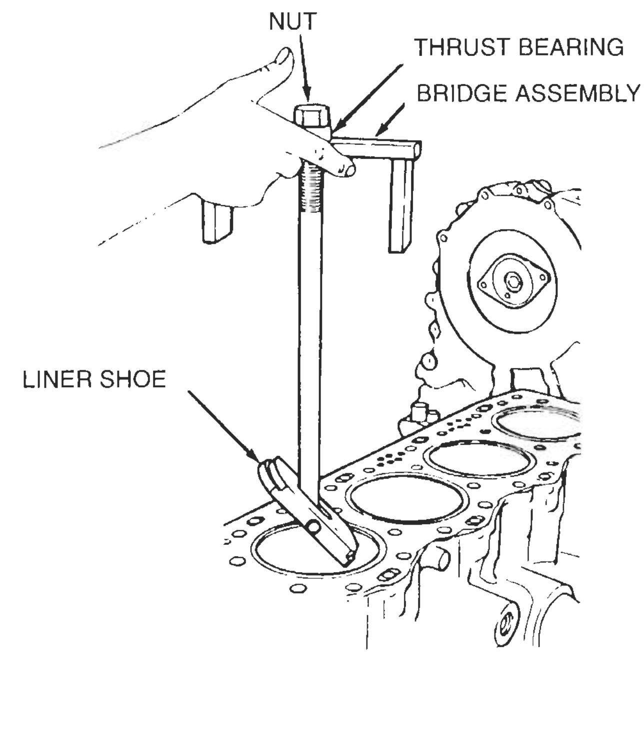


Figure 1–230 Cylinder Liner Remover

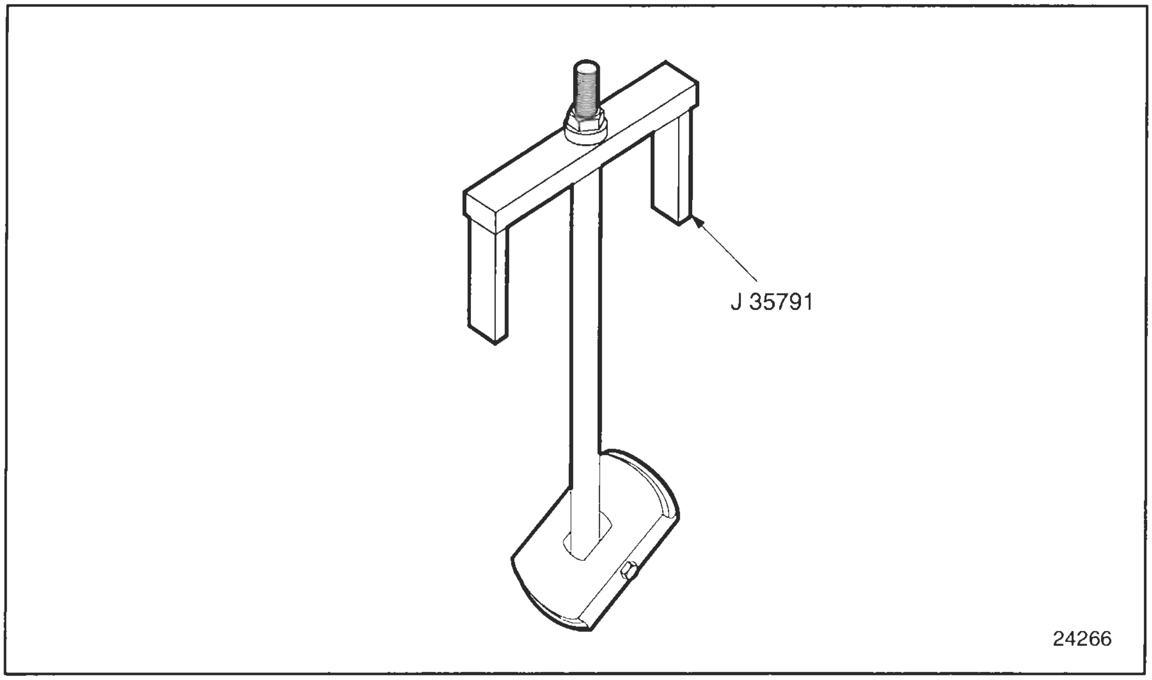


Figure 1–231 Cylinder Liner Removal Tool

[a] Ease the shoe of the liner removal tool down into the liner.

[b] Place the shoe into the bottom edge of the liner.

[c] Turn the nut on the tool in a clockwise direction to remove liner from the block.

NOTE:
After removing liners from an engine and prior to installing liners, always store them in an upright position until ready for use. Liners left on their side for any length of time can become egg–shaped and distorted, making installation in cylinder bores difficult or impossible. If the cylinder liners are to be reused, they should be marked so they may be installed to the same cylinder from which they were removed.

[d] Remove the tool from the liner

[e] Remove the seals (all 3) from the liner and discard them.

Clean the cylinder liner prior to inspection as follows:

1. Wash new and used cylinder liners with a strong detergent and warm water solution Scrub the cylinder liners with a non–metallic bristle brush.

2. Rinse the cylinder liners with hot water or steam.

CAUTION:
To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

3. Dry the liner with compressed air.
4. Coat the bore of the liner with clean engine lubricating oil.
5. Allow the liner to sit for 10 minutes (to allow the oil to work into the surface finish).
6. Wipe the inside of the liner with clean, white paper towels.
7. If a dark residue appears on the towels, repeat the oiling and wiping procedure until residue no longer appears.

NOTICE:
If the liners are not to be installed at this time, oil them lightly with clean engine lubricating oil and store them upright in a clean, dry area. Do not allow the liners to rest on their sides and do not store anything on top of the liners.

1.20.2.1 Inspection of Cylinder Liner

Inspect the cylinder liner as follows:

1. Inspect the cylinder liner.
   [a] Check the cylinder liner for cracks or scoring.
   [b] If any of these are detected, replace with a new part.

NOTICE:
Series 50 Engines cylinder liners are honed at the factory with a process that cannot be duplicated in the field. For this reason, honing of used liners should not be attempted.

   [c] Check the cylinder liner for cavitation erosion. See Figure 1–232.

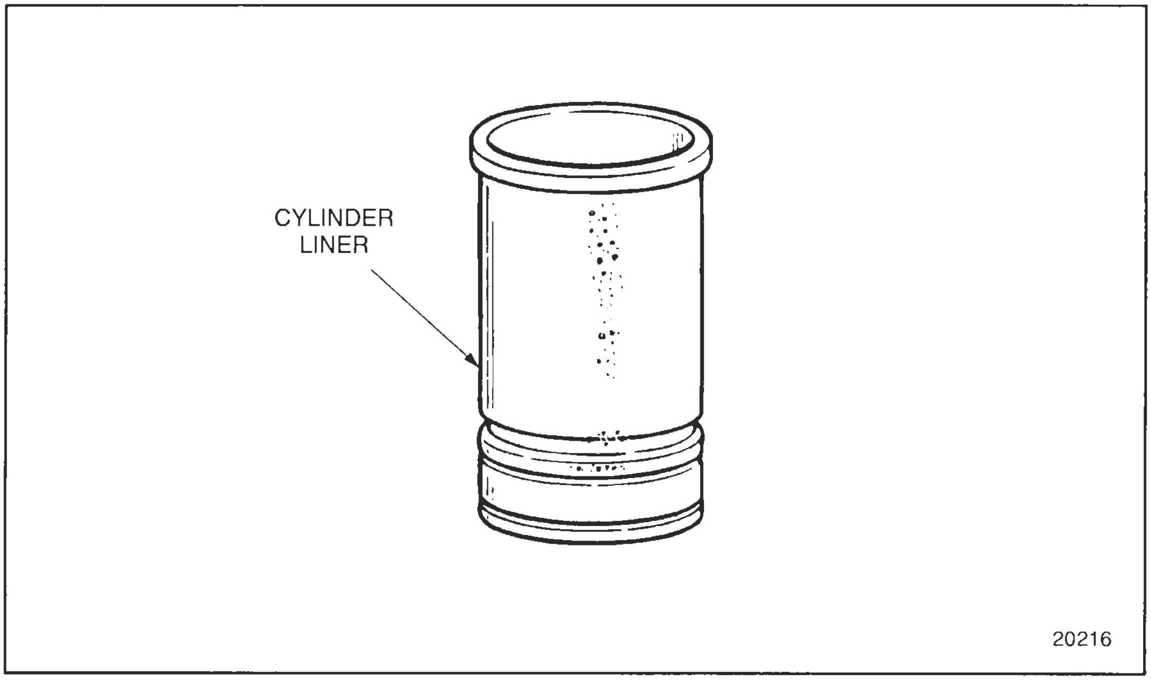


Figure 1–232 Cavitation Erosion

NOTICE:
Erosion is due to poor cooling system maintenance. If uncorrected, it will eventually make holes through the liner. This can result in combustion gases blowing water out of the radiator, oil in the coolant, or when the engine is stopped will allow water to flow into the cylinder and result in major engine damage due to water in the oil or hydraulic lockup.

[d] If cavitation erosion occurs, replace with a new part. Refer to section 1.20.3.

2. Inspect the outside diameter of the liner.

   [a] Check liner for fretting.

   [b] If any fretting is found, remove it from the surface of the liner with a coarse, flat stone.

3. Inspect the liner flange.

   [a] Check the liner flange for cracks, smoothness and flatness on both the top and bottom surfaces.

   [b] If these are detected, replace with a new part.

4. Inspect the block bore and cylinder liner.

   [a] Measure the block bore and the outside diameter of the liner. Refer to section 1.1.4.1. The liner specifications are listed in Table 1-11. The block specifications are listed in Table 1-10.

   [b] If the liner does not meet specs, replace with a new part.

5. Inspect inside diameter of cylinder liners.
   [a] Set the cylinder bore gauge on zero in master setting fixture. Use cylinder bore gage, J 5347–B, to measure diameter of the liner of various points. The maximum diameter of a used liner after is 130.100 mm (5.122 in.) at any measurement location. See Figure 1–233. Also check the liner for taper and out-of-round.

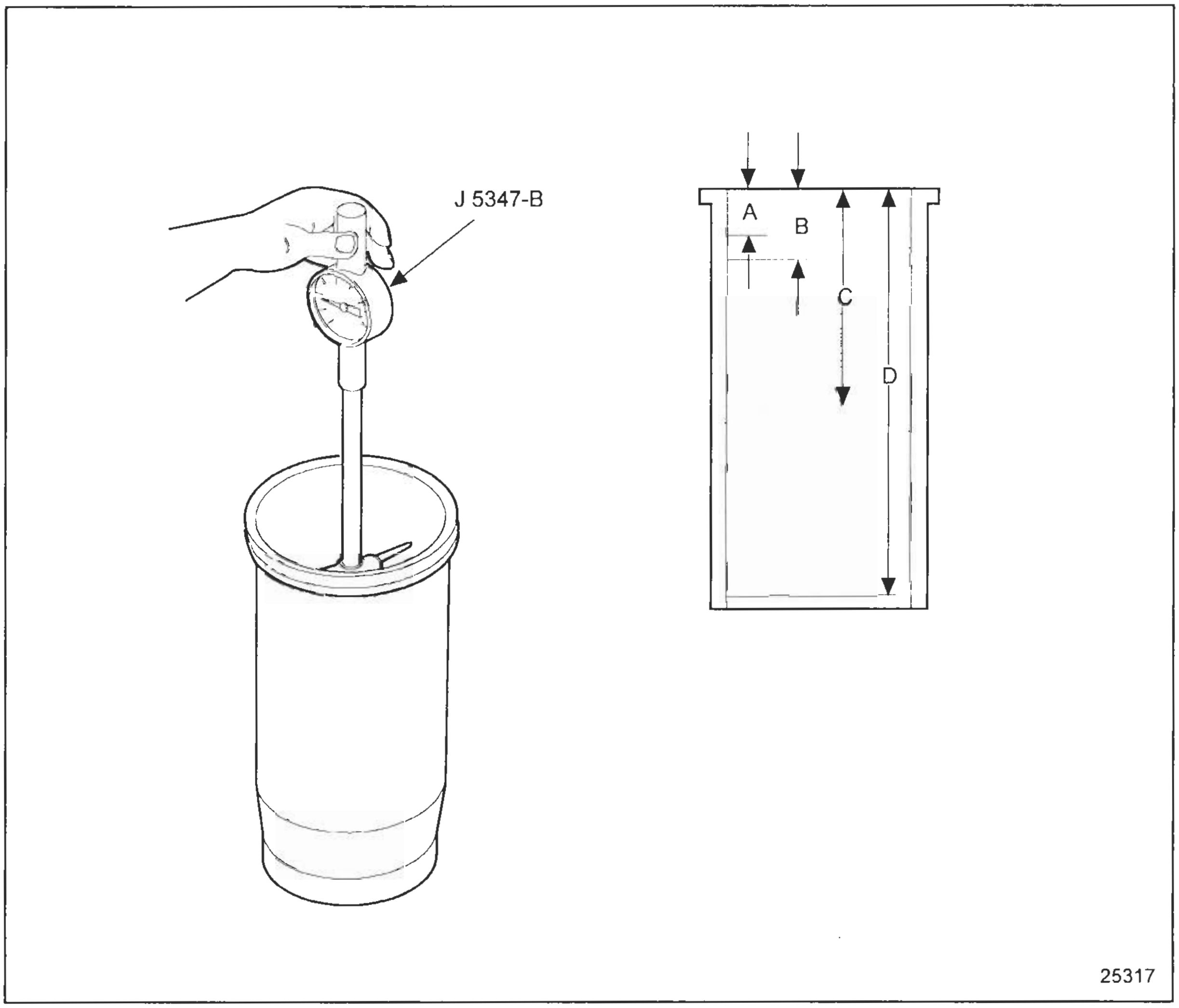


Figure 1–233 Cylinder Liner Measurement Diagram

   [b] If the taper and out-of-round exceed 0.025 mm (.0001 in.), replace with a new part.
6. Inspect the cylinder liner.
   [a] Check the seal ring and crevice seal grooves for burrs or sharp edges.
   [b] If any are detected, smooth with an emery cloth.

1.20.3 Installation of Cylinder Liner

Install the cylinder liner as follows:

1. Wipe the inside and outside of the liner clean. Be sure the block bore and counter bore are clean, so the liner flange will seat properly. The block counter bore depth must be 8.9246–8.9746 mm (.3514–.3533 in.) and must not vary more than 0.04 mm (.0015 in.) in depth around the circumference. No two adjacent block counter bores may range in depth more than 0.025 mm (.001 in.) when gaged along the longitudinal cylinder block centerline.

NOTE:
Thoroughly clean the cylinder block liner counter bores to remove any foreign material. Foreign material in the cylinder liner counter bores can cause the liner to seat improperly.

NOTE:
If the firedeck surface of the cylinder block has been machined, the counter bores must be machined the same amount to keep the cylinder liner counter bore depth within limits.

2. Lubricate the seal rings and crevice seal with clean petroleum jelly.
3. Install two new seal rings and a new crevice seal into their respective grooves in the liner.
4. Insert the cylinder liner into the cylinder bore.

NOTE:
Do not exert excessive force on the liner, while pushing it down.

5. Install the cylinder liner installation tool, J 35597, over the liner to be installed. See Figure 1–234.

NOTE:
It is necessary to leave the cylinder liner installation tool in place until after the liner protrusion is measured.

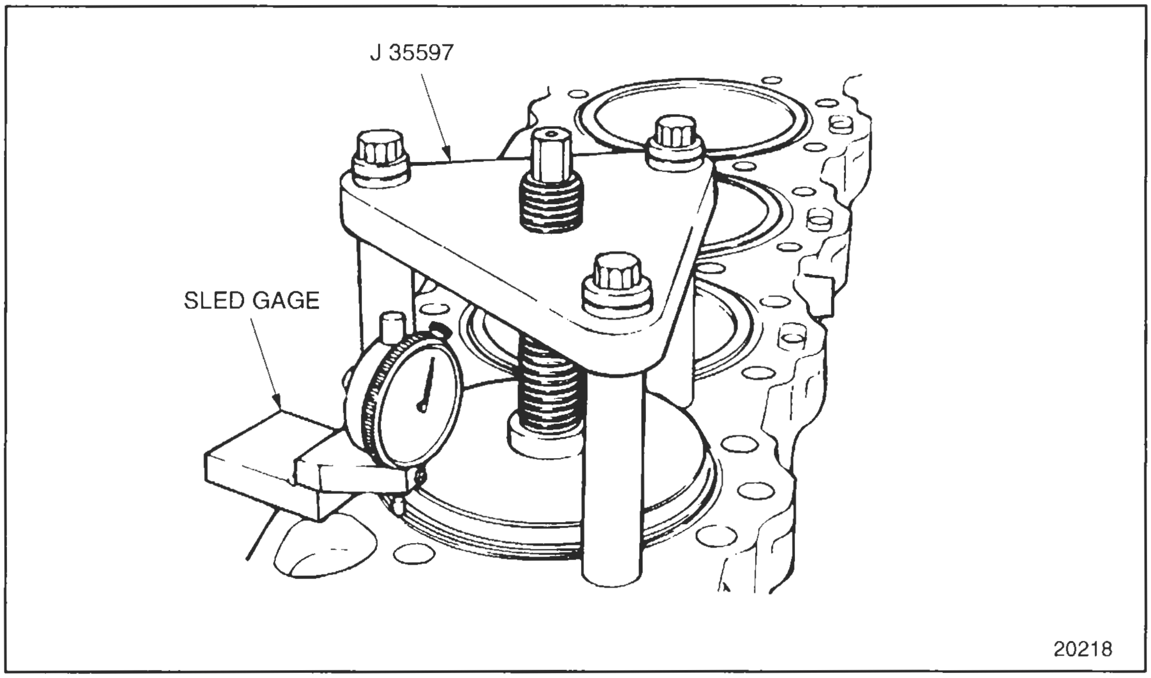


Figure 1–234 Cylinder Liner Installation Tools

6. Thread three cylinder head bolts through the tool and into a head bolt hole, so that the round shoe of the tool is centered over the liner.
7. Tighten the bolts.

NOTE:
It is not necessary to torque the bolts.

8. Turn the threaded center bolt in a clockwise direction. As the round shoe of the tool reaches the liner, ensure that the shoe is properly positioned into the cylinder liner.
9. Continue turning the bolt until the liner bottoms in the cylinder counterbore. Apply a tightening torque of 60 N·m (44 lb·ft) to the installation tool center bolt.
10. Install a dial indicator sled gage. See Figure 1–234.

11. Measure the distance from the top of the liner flange to the top of the block. See Figure 1-235.
    [a] Allowable liner protrusion is 0.000–0.076 mm (.000–.003 in.) with no more than 0.05 mm (.002 in.) variation between any two adjacent cylinders.
    [b] If the liner protrusion exceeds the maximum allowable, remove the liner and check for debris under the liner flange.

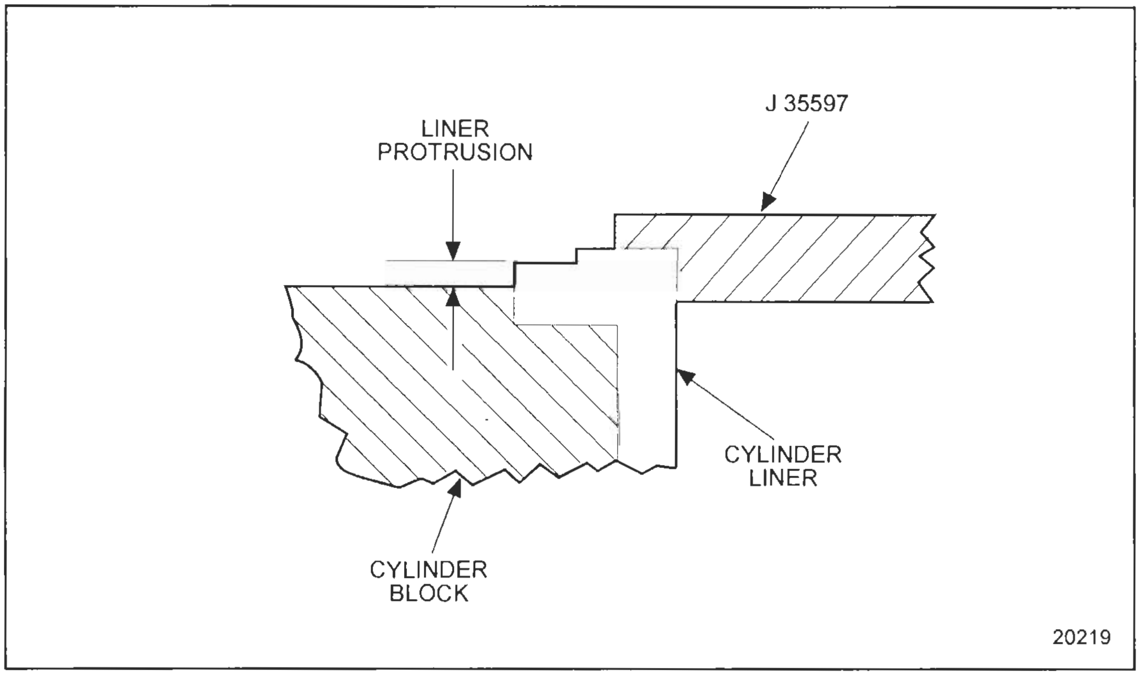


Figure 1–235 Cylinder Liner Protrusion

12. Remove the cylinder liner tool.
13. With all of the cylinder liners installed and the liner protrusion measurements within specifications, install the piston and connecting rod assemblies. Refer to section 1.18.5.
14. Refer to section 11.6 for verification of proper cylinder liner installation.

1.21 GEAR TRAIN AND ENGINE TIMING

The gear train is completely enclosed between the gear case and gear case cover and is located at the front of the engine. The gear train consists of a camshaft drive gear, camshaft idler gear, fuel pump drive gear, air compressor and power steering pump drive gear, bull gear, oil pump drive gear, crankshaft timing gear, water pump drive gear, accessory pulley drive gear, and adjustable idler gear. The gear ratio of each gear in relationship to the crankshaft timing gear is shown directly below the gear title. See Figure 1-236.

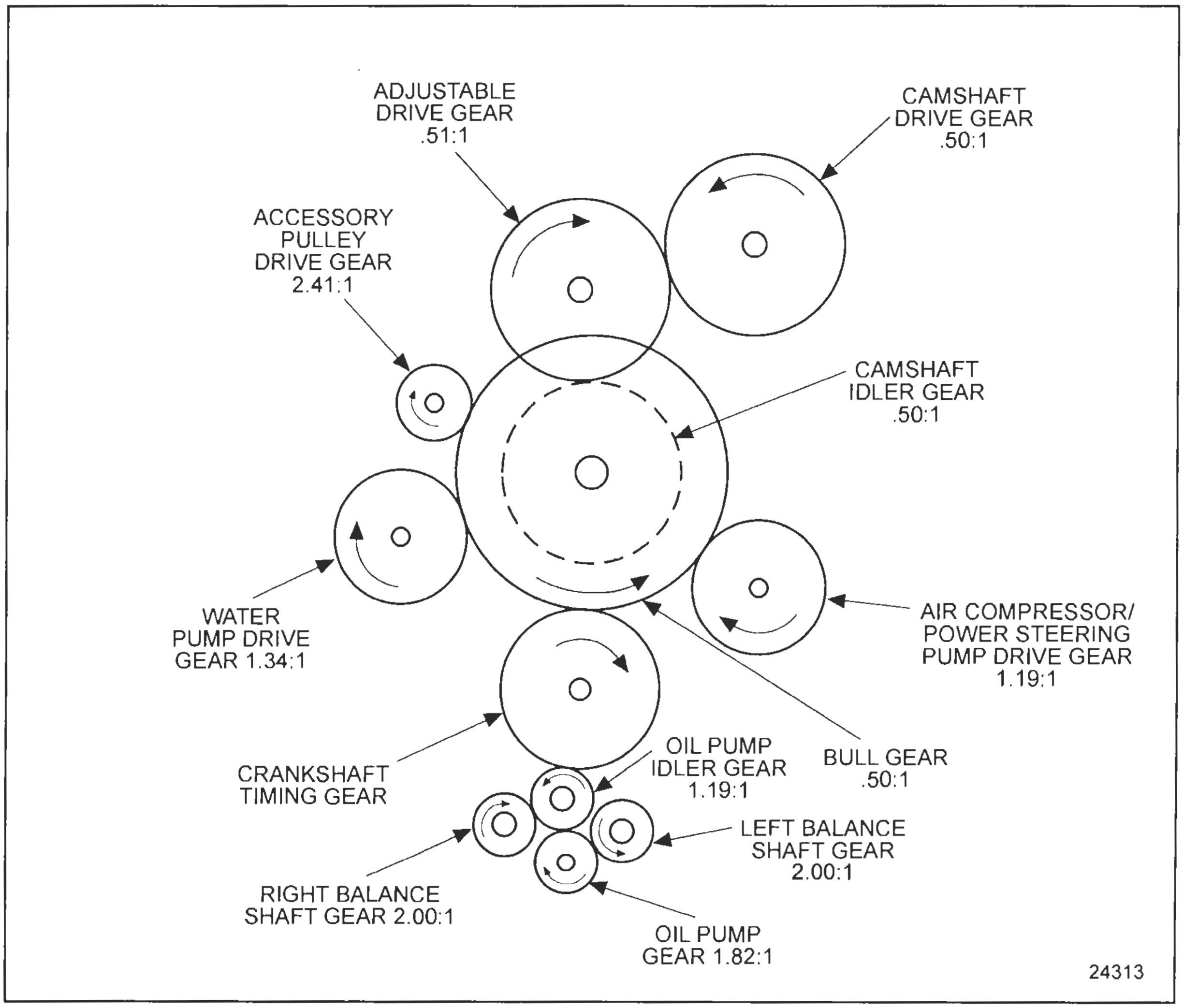
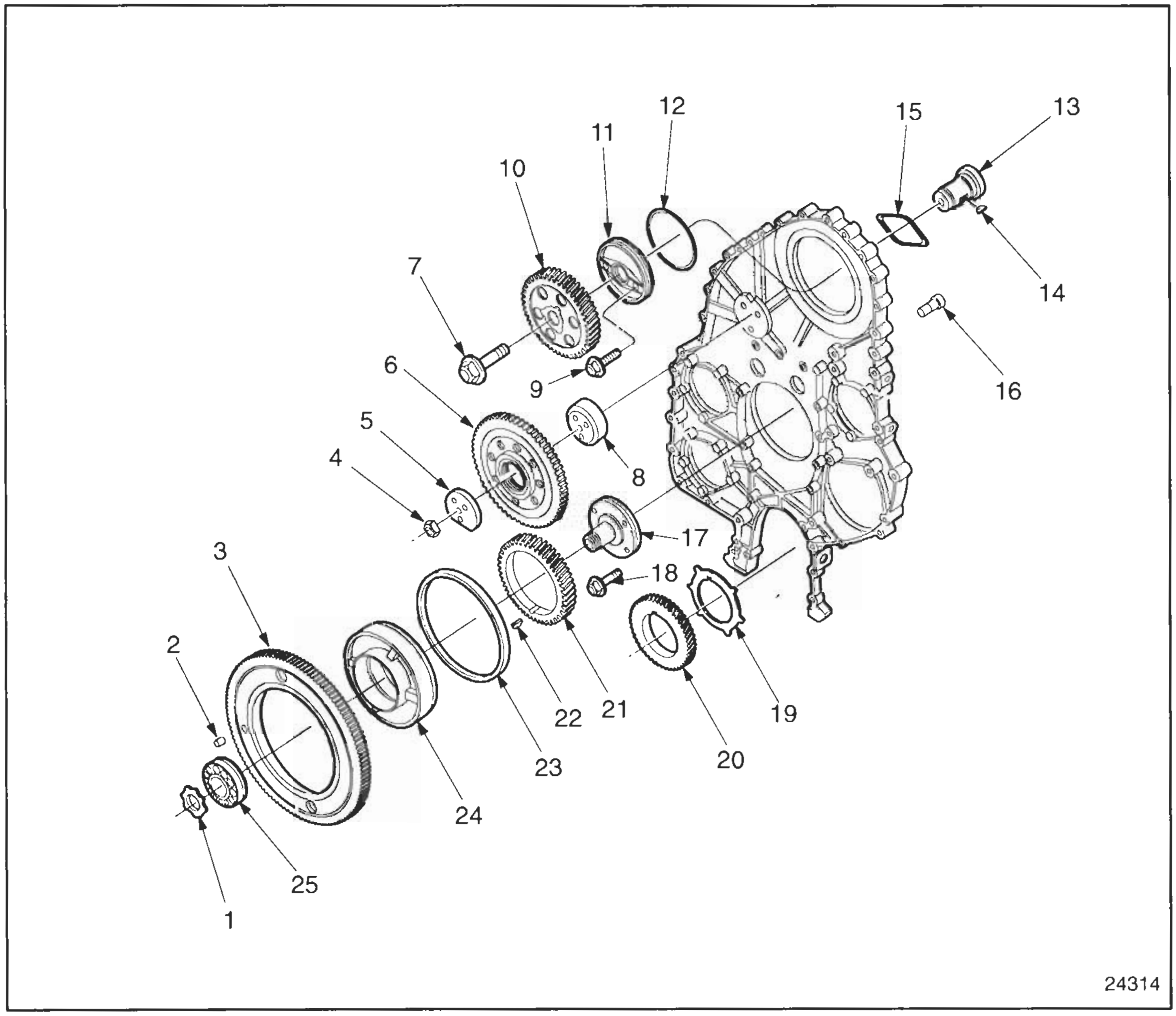


Figure 1–236 Engine Gear Train

The crankshaft timing gear, pressed onto the front end of the crankshaft, directly drives the bull gear and oil pump drive gear, and indirectly (through the bull gear), drives the fuel pump drive gear, air compressor and power steering pump drive gear, accessory pulley drive gear and water pump drive gear.

The camshaft idler gear is mounted to the rear of the bull gear on the same carrier, and rotates along with the bull gear at the same speed. This camshaft idler gear drives the adjustable idler gear, which in turn, drives the camshaft drive gear. See Figure 1-237.



1. Bull Gear Retaining Nut
2. Timing Pin
3. Bull Gear
4. Adjustable Idler Gear Locknut (3)
5. Adjustable Idler Gear Plate
6. Adjustable Idler Gear
7. Camshaft Retaining Bolt
8. Adjustable Idler Gear Hubt
9. Thrust Plate Retaining (2) Bolt
10. Camshaft Drive Gear
11. Camshaft Thrust Plate
12. Camshaft Thrust Plate Seal O–ring
13. Camshaft Drive Gear Hub
14. Camshaft Drive Gear Hub Key
15. Camshaft Thrust Plate Seal
16. Adjustable Idler Gear Hub Retaining Stud
17. Bull Gear/Idler Gear Hub
18. Bull Gear Hub Retaining (4) Bolt
19. Crankshaft Timing Ring
20. Crankshaft Timing Gear
21. Camshaft Idler Gear
22. Bull Gear/Idler Gear Key
23. Spacer
24. Bull Gear/Idler Gear Carrier
25. Bull Gear/Idler Gear Bearings

Figure 1–237 Gear Train and Related Parts

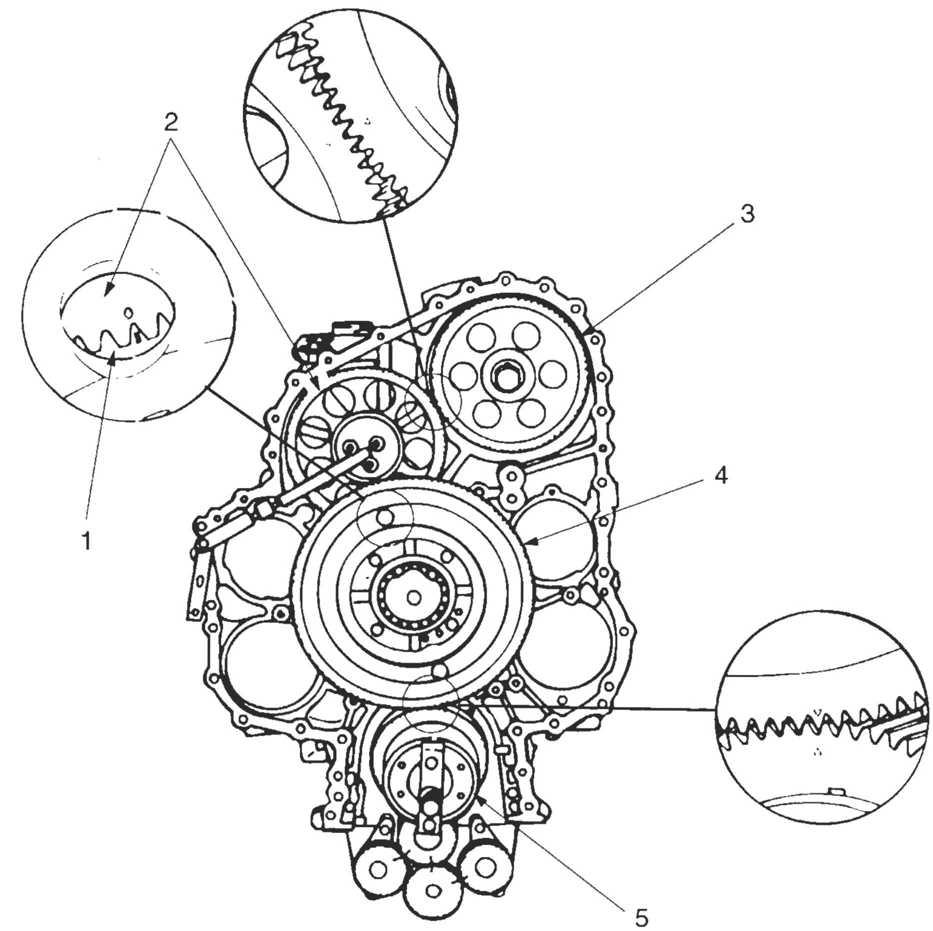
The bull gear and camshaft idler gear are a press–fit to the bull gear and camshaft idler gear carrier. Both gears are keyed to the carrier by the same key. The carrier is supported by two tapered roller bearings, which ride on a hub bolted to the engine block by four bolts. The bull gear and camshaft idler gear assembly is retained to the hub by a **left–hand threaded nut**.

The camshaft idler gear drives the camshaft drive gear through an adjustable idler gear. The adjustable idler gear is supported by a bushing and is mounted on an adjustable hub secured by three studs pressed into the gear case from the rear.

The balance shaft idler gear drives the right balance shaft gear and oil pump gear. The oil pump gear drives the left hand balance shaft, causing the balance shafts to counter–rotate.

The camshaft must be in time with the crankshaft timing gear. Since there are three gears between them, timing marks have been stamped or etched on the face of the gears to facilitate correct gear train timing. See Figure 1–238.

The balance shafts must be in time with the crankshaft. Timing marks are stamped on the balance shaft idler gear, balance shaft gears, and oil pump gear.



1. Camshaft Idler Gear
2. Adjustable Idler Gear
3. Camshaft Drive Gear
4. Bull Gear
5. Crankshaft Timing Gear

Figure 1–238 Engine Gear Train and Timing Marks

The symbol system of marking the gears makes gear train timing a comparatively easy operation. When assembling the engine, work from the crankshaft timing gear to the camshaft drive gear and line up the appropriate symbols on the gears as each gear assembly is installed on the engine.

There are no timing marks on the drive gears for the fuel pump, air compressor and power steering pump, water pump or accessory drive pulley. Therefore, it is not necessary to align these gears in any particular position during their installation.

Alignment of the symbols on the balance shaft idler gear, balance shaft drive gears, and oil pump gear is done with balance shaft counter weights in the bottom, 6 o'clock, position and cylinder number one at TDC.

The backlash between the various mating gears in the gear train should be .051–.229 mm (0.002 in.–0.009 in.), and should not exceed .305 mm (0.012 in.) backlash between worn gears.

Gear train noise is usually an indication of excessive gear lash, chipped, pitted or burred gear teeth or excessive bearing wear. Therefore, when noise develops in a gear train, the gear case should be removed and the gear train and its bearings inspected. A rattling noise usually indicates excessive gear lash whereas a whining noise indicates too little gear lash.

The gear train is lubricated by oil splash. The bull gear and camshaft idler gear are pressure–fed lubricating oil through two holes in the bull gear recess area of the engine block. See Figure 1–239.

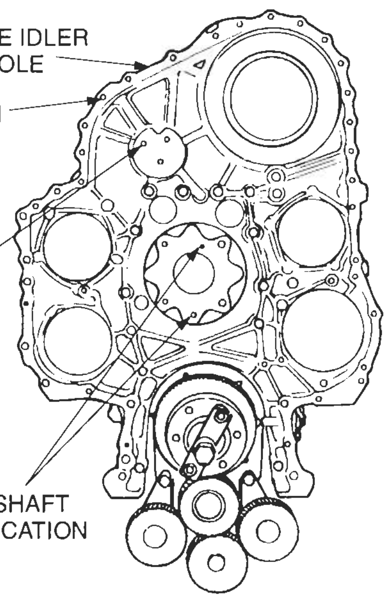


Figure 1–239 Gear Train Lubricating Oil Hole Locations

These two holes are connected to the main oil gallery. The adjustable idler gear assembly is pressure–fed by an oil gallery in the gear case that indexes with a hole in the engine block. The hole in the engine block is connected to the main oil gallery.

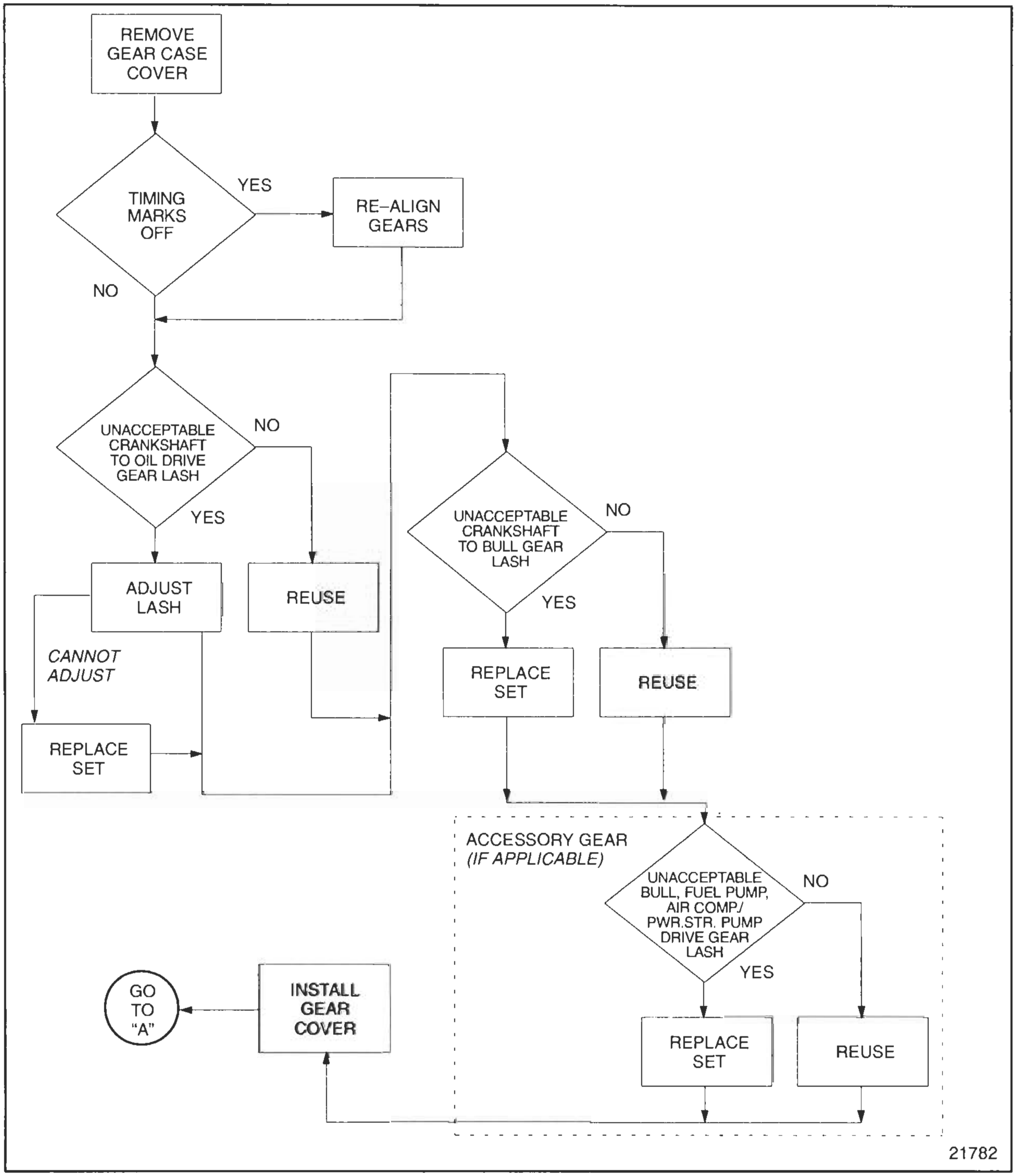
The correct relationship between the crankshaft and the camshaft must be maintained to properly control the opening and closing of the intake and exhaust valves, and the operation of the fuel injectors and to help maintain engine balance.

The crankshaft and camshaft gears can only be mounted in one position as they are both keyed to their mating parts. Therefore, when the engine is properly timed, the timing marks on the various gears will match. See Figure 1–238.

An “out of time” engine may result in valve–to–piston dome contact, a no–start condition or loss of power.

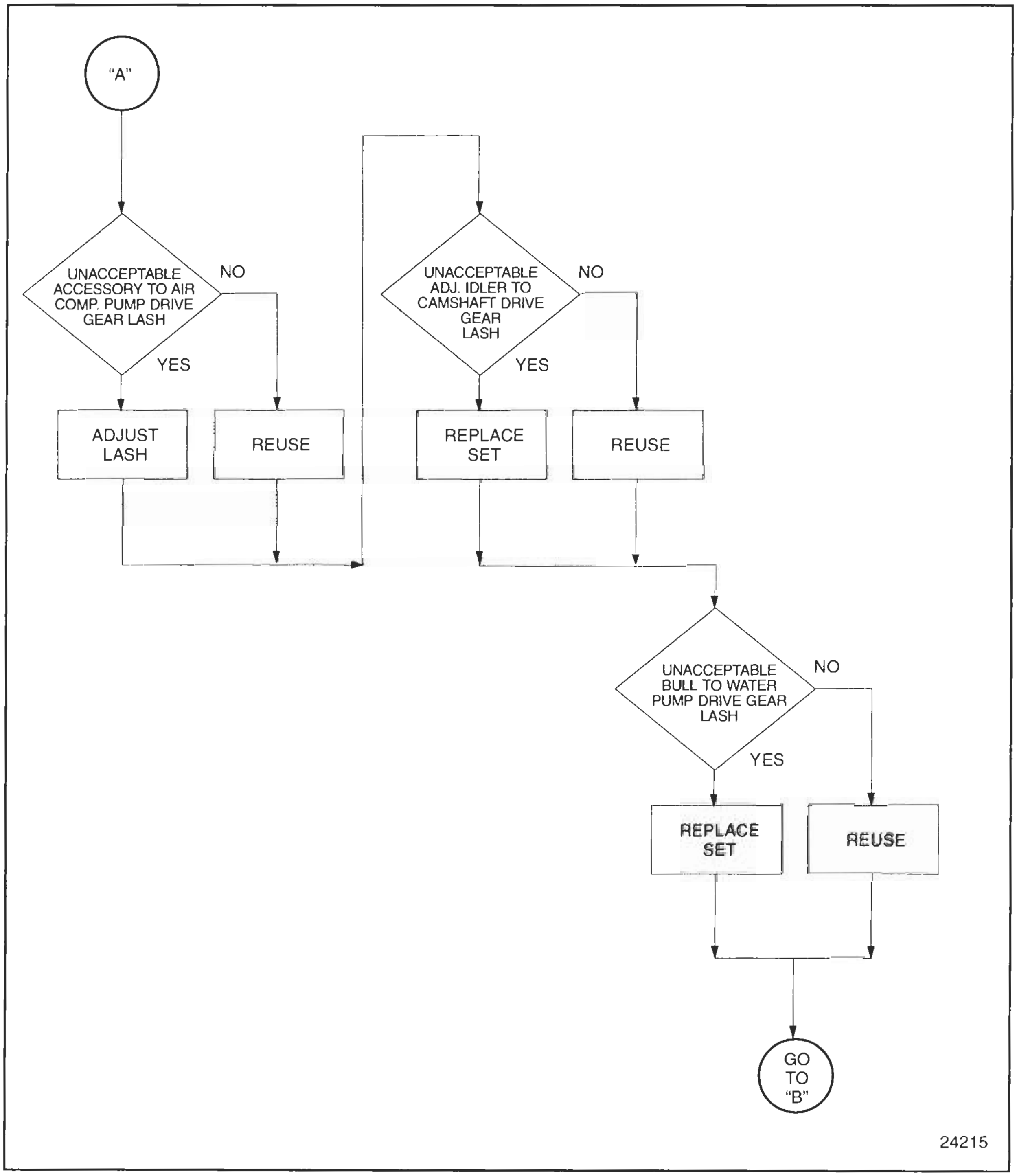
1.21.1 Repair or Replacement of Gear Train and Engine Timing

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 1-240.



To go to "A", see Figure 1-241 To go to "B", see Figure 1-242

Figure 1-240 Flowchart for Repair or Replacement of Gear Train and Engine Timing – Part 1 of 3



To go to "B", see Figure 1–242

Figure 1–241 Flowchart for Repair or Replacement of Gear Train and Engine Timing – Part 2 of 3

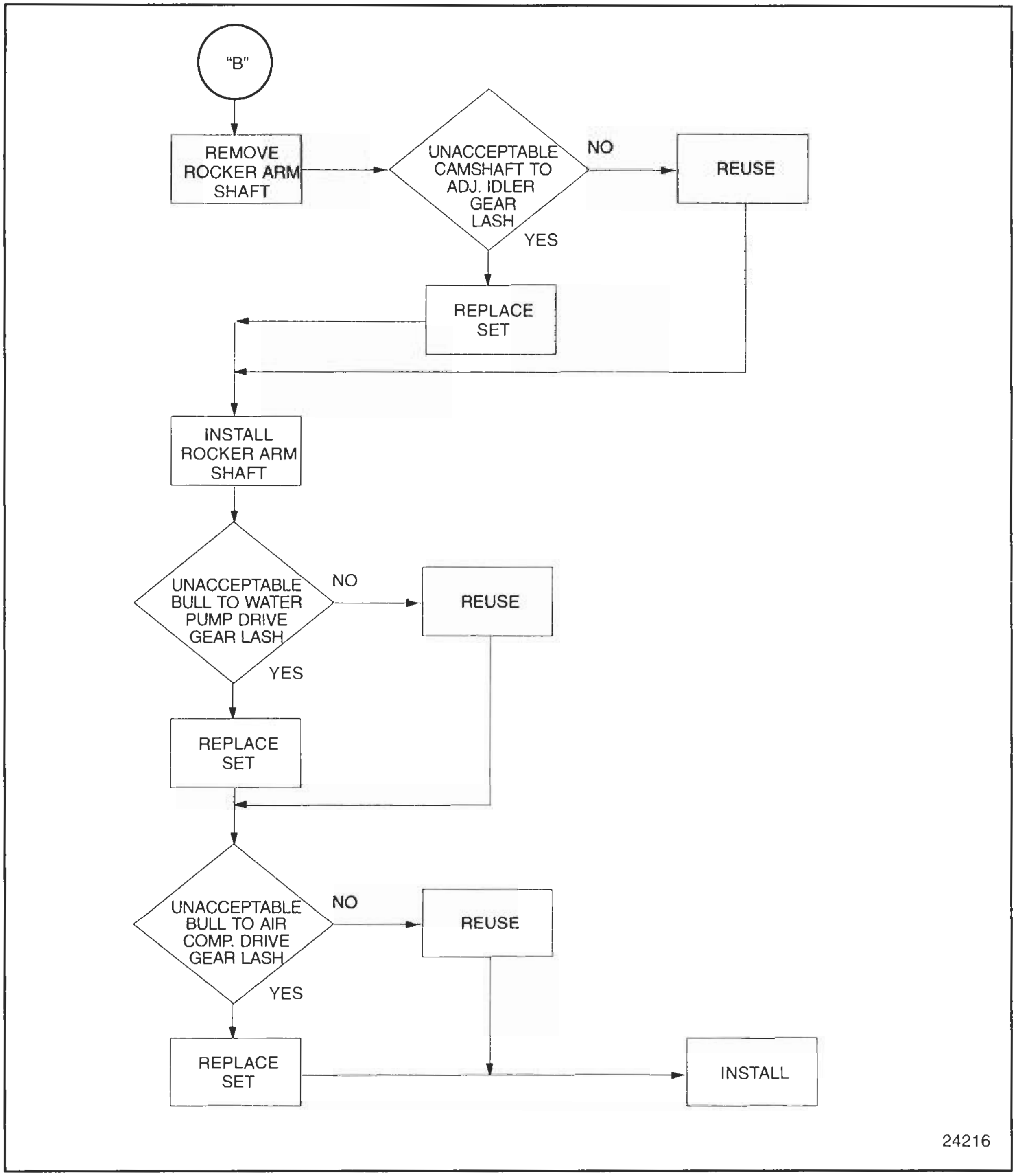


Figure 1–242 Flowchart for Repair or Replacement of Gear Train and Engine Timing – Part 3 of 3

1.21.2 Cleaning and Removal of Gear Train and Engine Timing

When an engine is out of time, the camshaft timing can be checked by following the camshaft timing check procedure. Refer to section 1.22.6.1. If the engine is out of time, a visual inspection of the gear train is required.

Refer to section 1.10.2 and perform all of the steps under "Removal of Gear Case Cover".

1.21.2.1 Check Engine Timing

Gear train noise is usually an indication of excessive gear lash, chipped, pitted or burred gear teeth, or excessive bearing wear. Therefore, when noise develops in a gear train, the gear case cover should be removed and the gear train and its bearings inspected. A rattling noise usually indicates excessive gear lash. A whining noise indicates too little gear lash.

1. Check engine timing as follows:
   [a] Examine all timing marks to ensure they are aligned. See Figure 1–238.

NOTE:
The gear ratio between the adjustable idler gear and the camshaft drive gear causes a "hunting–tooth" situation. Therefore, the bull gear and rocker arm assemblies should be removed to align the timing marks. See Figure 1–238.

   [b] It may be necessary to remove the gears to align the timing marks. Refer to section 1.25.2.
   [c] If any gears are removed or installed, or if lash between any two gears is out of specification, check the lash between the mating gears.

2. Check the crankshaft timing gear–to–oil pump idler gear lash measurement as follows:
   [a] Fasten a dial indicator and magnetic base to the cylinder block so that the stem of the dial indicator rests on a tooth of the balance shaft idler gear. See Figure 1–243.

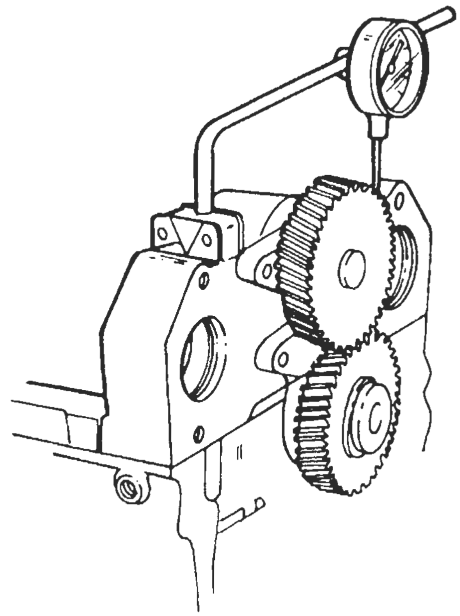


Figure 1–243 Crankshaft Timing Gear–to–Oil Drive Gear Lash Measurement

NOTE:
The lash between the crankshaft timing gear and oil pump idler gear must be measured with the engine in a running position. See Figure 1–238.

   [b] Hold the crankshaft timing gear stationary, and rotate the balance shaft idler gear in one direction, as far as it will go, without moving the crankshaft timing gear.
   [c] Zero the dial indicator.
   [d] Move the balance shaft idler gear in the opposite direction, as far as it will go, without moving the crankshaft timing gear.
   [e] Read and record the total gear lash.

NOTE:
The gear lash must be checked in four positions 90° apart.

Proper lash between the crankshaft timing gear and balance shaft idler gear is 0.051–0.229 mm (.002–.009 in.) for new parts, with a maximum of 0.305 mm (.012 in.) for used parts.

The gear lash between the crankshaft timing gear and the balance shaft idler gear can be adjusted utilizing shims inserted between the balance shaft assembly and the cylinder block. See Figure 1-244.

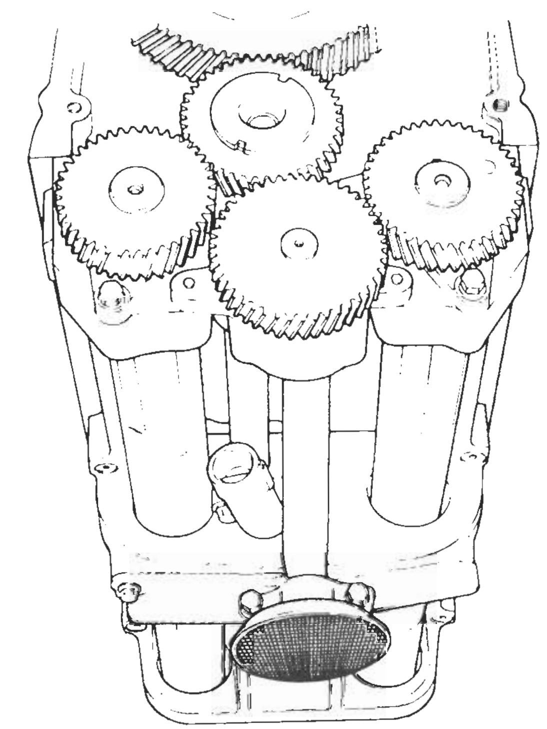


Figure 1-244 Lubricating Oil Pump Shim Installation

[f] Remove or install shims as necessary to obtain the proper gear lash clearance.

[g] If the use of shims cannot bring gear lash within acceptable limits, the gear or gears for that gear set must be replaced.

3. Check the crankshaft timing gear–to–bull gear lash measurement as follows:

   [a] Install a dial indicator and magnetic base. See Figure 1–245.

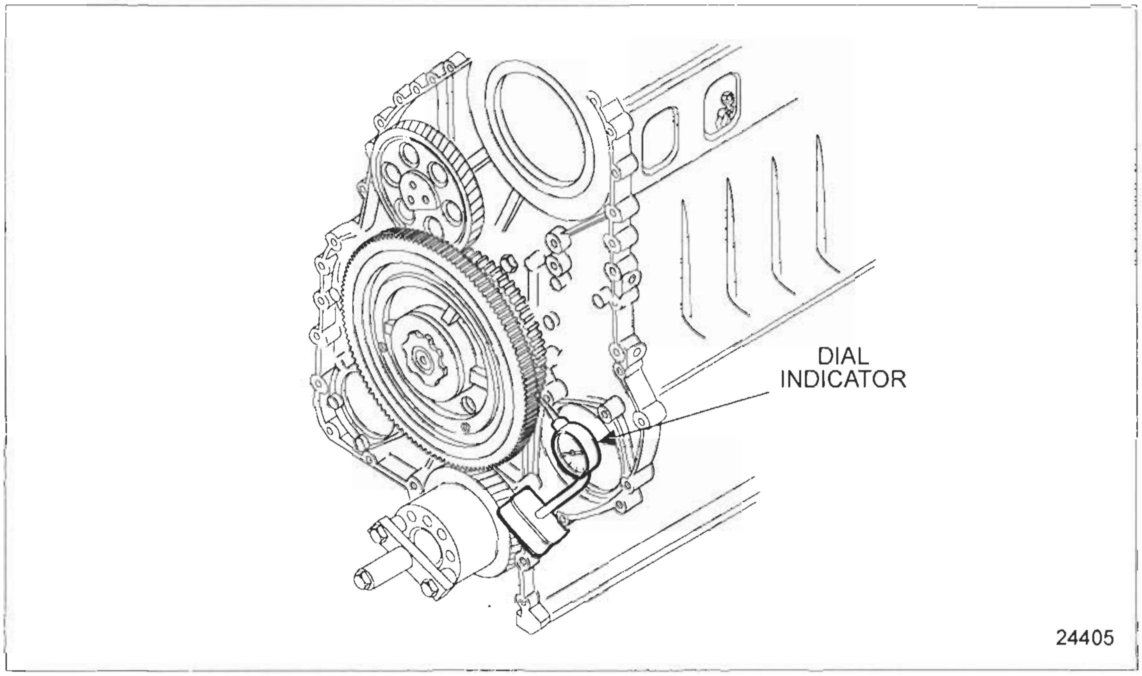


Figure 1–245 Crankshaft Timing Gear–to–Bull Gear Lash Measurement

   [b] Adjust the stem of the dial indicator to rest on the center of a tooth on the bull gear.

   [c] Preload the bull gear.

   [d] Zero the dial indicator pointer.

   [e] Hold the crankshaft timing gear stationary with one hand. Rotate the bull gear and check the total gear lash in four positions of crank gear, approximately 90° apart.

   [f] Although gear lash for the remaining gear sets is not adjustable, the lash must still be measured. Lash specifications is 0.051–1.229 mm (.002–.009 in.) for new parts and a maximum of 0.305 mm (.012 in.) for used parts.

   [g] If lash measurement is exceeded, replace gear with a new part.

4. The procedure for measuring the lash between the bull gear and the fuel pump drive gear (if applicable) and the air compressor and power steering pump drive gear is similar to the steps just mentioned. Refer to step [a], as the first step and refer to step [g], as the final step.

5. Gear case cover must be installed to continue or checking the engine timing. Refer to section 1.8.4 and perform all of the steps under gear case cover installation.

6. The procedure for measuring the lash between the accessory drive gear and air compressor pump drive gear (on vehicle without power steering) is similar to the steps just mentioned. Refer to step 3., as the first step and refer to step 9., as the final step.

NOTE:
Lash can be measured with the gear case cover installed. Access covers are provided for checking the lash between these gears and the bull gear. For engines with no access cover for accessory drive gear lash is to be measured off the accessory drive pulley.

7. The procedure for measuring the lash between the adjustable idler gear and camshaft drive gear is similar to the steps just mentioned. Refer to step 3., as the first step and refer to step 9., as the final step.

NOTE:
These gears are measured and adjusted with the gear case cover installed.

8. The procedure for measuring the lash between the bull gear and the water pump drive gear is similar to the steps just mentioned. Refer to step 3., as the first step and refer to step 9., as the final step.

NOTE:
These gears can be measured with the pump installed.

Refer to section 1.3.2 and perform all of the steps under "Removal of Rocker Arm Assembly," in order to continue checking the engine timing.

9. When measuring or adjusting the gear lash between the adjustable idler gear and the camshaft drive gear, the valve and injector spring pressures must be removed from the camshaft lobes. Use the following procedure for this adjustment:

NOTE:
The front and rear rocker arm shafts look identical, but must not be interchanged due to different oil passage patterns. The outboard ends of the rocker arm shafts are marked for identification with the DDC logo. See Figure 1–246. Use care to ensure that the rocker arm shaft assemblies are replaced exactly as removed.

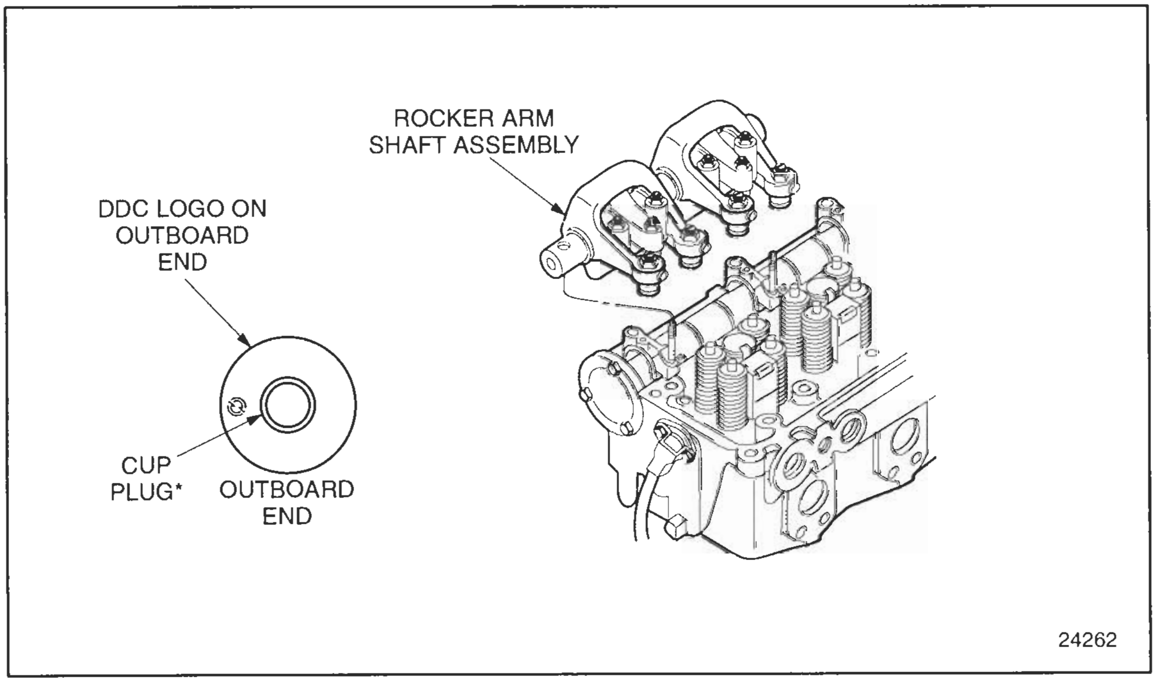


Figure 1–246 Rocker Arm Shaft Identification Mark

[a] Install the gear lash pedestal, J 35596–15, into the threaded hole of the camshaft drive gear. Bar the engine over until the tool is at the three o'clock position. See Figure 1–247.

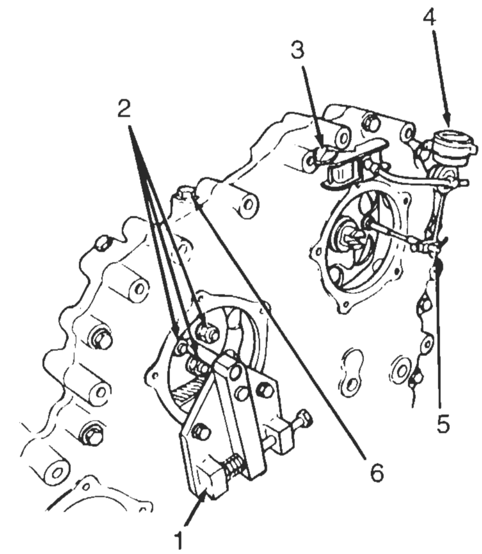


Figure 1–247 Camshaft Drive Gear–to–Adjustable Idler Gear Lash Measurement

NOTE:
Since the teeth of the camshaft drive gear are not accessible with the gear case cover installed, the lash is measured on the pedestal installed in the threaded hole, which is located exactly half–way between the center and edge of the camshaft drive gear. For this reason, the reading obtained will be exactly 1/2 of the actual gear lash.

[b] Mount a dial indicator adaptor and dial indicator. See Figure 1–247.

[c] Adjust the stem of the dial indicator to rest on the flat of the pedestal.

[d] If the adjustable idler gear has been removed, torque the three flanged nuts that retain the adjustable idler gear hub to the gear case to 57–67 N·m (42–49 lb·ft) to seat the assembly before proceeding.

[e] Loosen the three locknuts that retain the adjustable idler gear hub to the gear case until they are hand tight.

[f] Insert the dowel portion of the gear lash adjusting tool, J 35596, through the hole in the adjustable idler gear retaining plate and into the adjustable idler gear hub, using the bottom two adjustable idler gear cover bolt holes. See Figure 1–247.

[g] Turn the adjusting screw of the tool in a clockwise direction to force the adjustable idler gear against the camshaft drive gear, until there is zero lash between the two gears. See Figure 1-248.

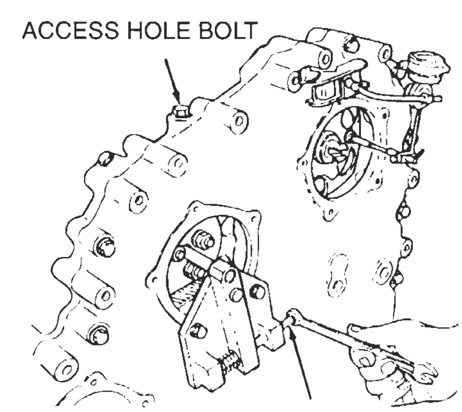


Figure 1–248 Adjustable Idler Gear–to–Camshaft Drive Gear Lash Adjustment

[h] Zero the dial indicator.

[i] Hold the adjustable idler gear by inserting a screwdriver through the hole provided in the gear case. Engage one of the adjustable idler gear teeth and apply pressure on the screwdriver to move the gear in a counterclockwise direction. This will prevent the gear from moving.

[j] Attempt to turn the camshaft drive gear, and watch the dial indicator pointer.

NOTE:
If there is zero lash between the two gears, the dial indicator pointer will not move from zero.

[k] Turn the adjusting screw of the tool approximately 1-1/2 turns or until the proper gear lash is obtained.

[l] When checking gear lash, hold the adjustable idler gear stationary. Refer to step [i] as the first step and refer to step [j] as the final step, and rotate the camshaft drive gear with your right hand. See Figure 1–249.

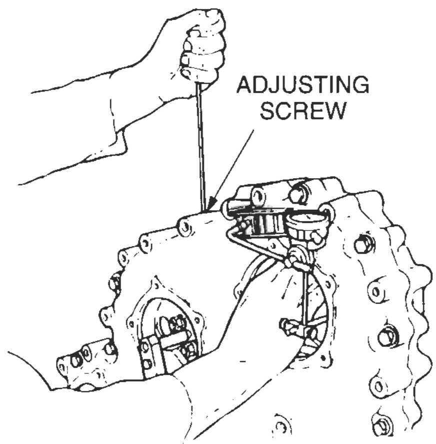


Figure 1–249 Checking Adjustable Idler Gear–to–Camshaft Drive Gear Lash

NOTE:
Remember to multiply the reading obtained by two to get the actual lash measurement. The specification of gear lash is 0.051–0.229 mm (.002–.009 in.) with a maximum of 0.305 mm (.012 in.) for used parts.

[m] Check the gear lash with the pedestal at the 3,6,9 and 12 o'clock positions, exactly as previously performed.

[n] When the proper readings of 0.025–0.114 mm (.001–.0045 in.) are obtained at all four (4) positions, hold the idler gear. Refer to step [i] as the first step and refer to step [j] as the final step, and tighten the top two adjustable idler gear flanged nuts to 57–67 N·m (42–49 lb·ft) torque.

[o] Check the gear lash again as outlined above, with the flanged nuts torqued, to ensure that gear lash is still within limits.

[p] If proper lash measurement cannot be obtained, replace gear(s) with new part(s). Refer to section 1.25.3.

[q] Remove the gear lash adjusting tool from the gear case.

[r] Torque the bottom adjustable idler gear flanged nut to 57–67 N·m (42–49 lb·ft) torque.

[s] Remove the dial indicator and pedestal from the gear case.

[t] Before installing the rocker arm shaft assemblies, check the torque on the end studs to ensure they were not loosened at time of removal. The torque specification is 101–116 N·m (75–86 lb·ft).

[u] Install the front and rear rocker arm shaft assemblies to the cylinder head. Install the six rocker arm shaft thru–bolts and two nuts, finger tight.

[v] Install the rocker arms and tighten the rocker arm shaft's thru–bolts and nuts to 101–116 N·m (75–86 lb·ft) using the sequence. See Figure 1–250.

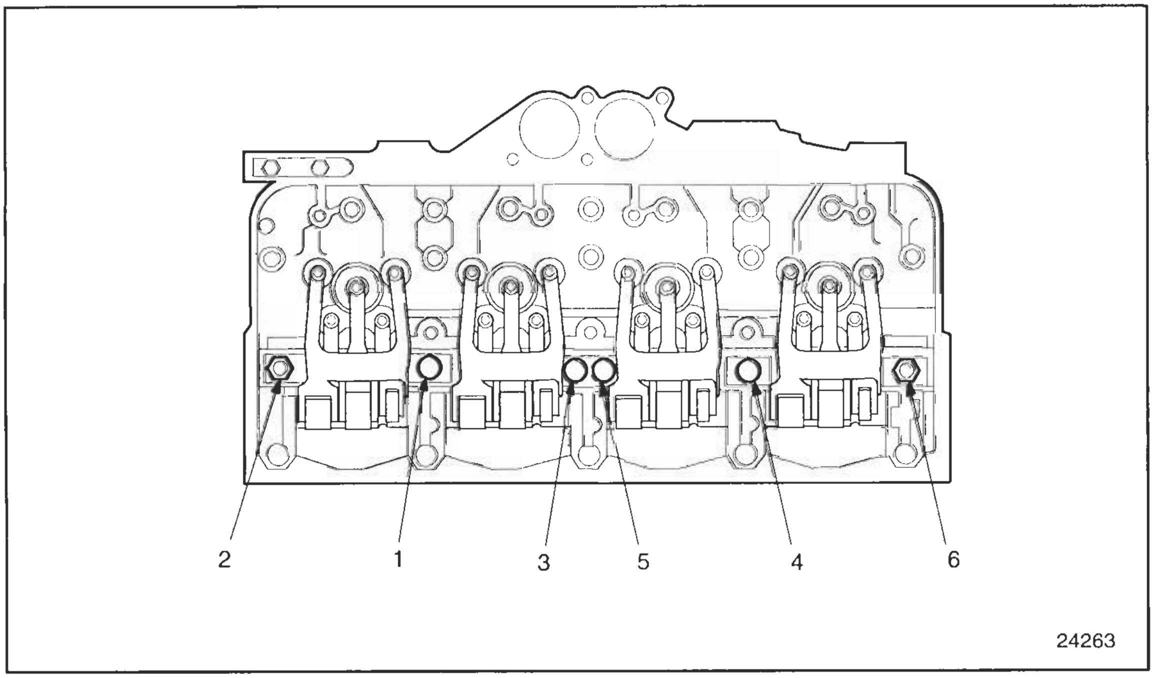


Figure 1–250 Rocker Arm Shaft Bolt and Nut Torque Sequence

[w] Refer to section 12.2 and adjust the intake and exhaust valve clearances, and fuel injector heights.

[x] Install the rocker cover. Refer to section 1.6.4.

[y] Insert a new gasket between the camshaft drive gear access cover and the gear case cover. Install the camshaft drive gear access cover to the gear case cover. Tighten the bolts to 30–38 N·m (22–28 lb·ft) torque using the tightening sequence. See Figure 1–251.

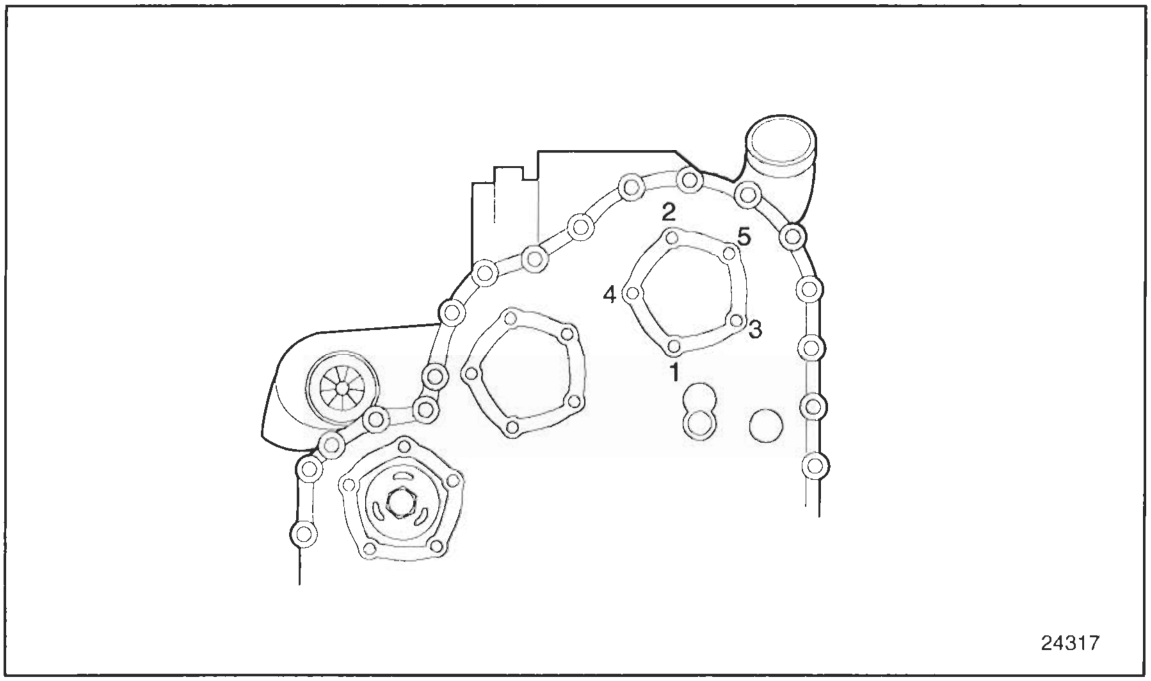


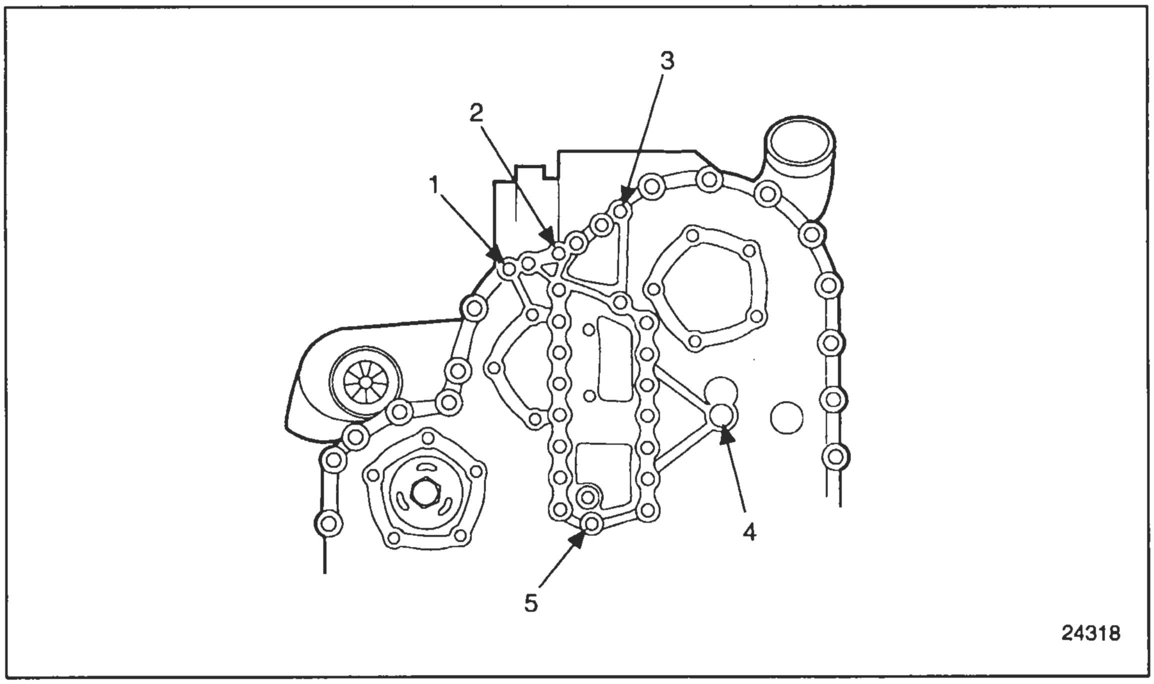
Figure 1–251 Camshaft Drive Gear Access Cover Bolt Torque Sequence

[z] Install the fan support bracket if required as follows:

Clean the mating surfaces of the fan support bracket and gear case of all old gasket eliminator. Gasket eliminator removal information may be found in the "General Information" section of this manual.

Apply a 1/16 in. bead of Gasket Eliminator PT-7276 (Loctite 51580), or equivalent, to the machined surface of the gear case cover surrounding the adjustable idler gear access.

Install the fan support bracket to the gear case cover using the torque values and tightening sequence. See Figure 1-252.



BOLT	TORQUE
1-3-5	58-73 N·m (43-45 lb·ft)
2-4	160-200 N·m (118-148 lb·ft)
6 to 10	30-38 N·m (22-28 lb·ft)

Figure 1-252 Fan Support Bracket Bolt Torque Sequence

10. Check the bull gear–to–accessory drive gear lash measurement as follows:

    [a] Mount a magnetic dial indicator base and dial indicator to the gear case cover. See Figure 1–253.

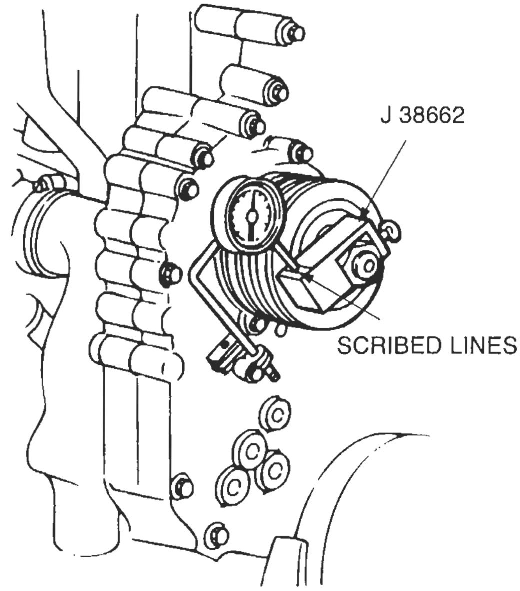


Figure 1–253 Accessory Drive Gear–to–Bull Gear Lash Measurement

    [b] Install the gear lash tool J 38662. See Figure 1–253.

    [c] Position the dial indicator to read between the scribed lines on the tool. See Figure 1–253.

    [d] Rotate the accessory drive pulley, read and record the total gear lash.

    [e] Lash should be 0.051–0.229 mm (.002–.009 in.) for new parts, with a maximum of 0.305 mm (.012 in.) for used parts.

    [f] If proper lash measurement cannot be obtained, replace gear with a new part. Refer to section 1.25.2.

    [g] Remove the dial indicator and gear lash tool.

11. Check the bull gear–to–water pump drive gear lash measurement with water pump impeller slip tester, J 35687 as follows:

NOTE:
The bull gear–to–water pump drive gear lash can be measured using the water pump impeller slip tester, J 35687, refer to step 11. Or by using the water pump gear lash tool; J 38977–A, refer to step 1.

CAUTION:

Due to the size and tension of the ring, use snap ring pliers of a type to ensure maximum safety whenever removing or installing the water pump cover snap ring. Wear adequate eye protection, and press a hammer against the pump cover to help prevent personal injury, should the snap ring slip off the pliers.

[a] Remove the water pump cover snap ring with snap ring pliers. Remove water pump cover and seal ring.

[b] Install the water pump impeller slip tester, J 35687, to the water pump impeller with two 5/16–18 bolts, using the instructions supplied with the tool. See Figure 1–254.

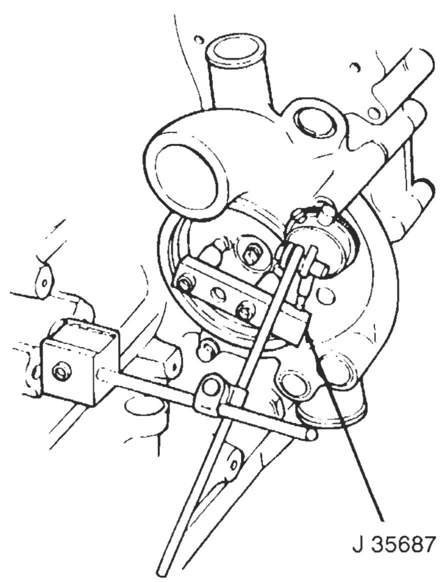


Figure 1–254 Water Pump Impeller Slip Tester Method

[c] One leg (the long one) of the tool has an inscribed line. Measuring with a dial indicator at this line of the tool, the gear lash measurement will be an exact 1:1 reading. Lash should be 0.051–0.229 mm (.002–.009 in.).

[d] If proper lash cannot be obtained, replace gear with a new part.

[e] Remove the dial indicator.

[f] Remove the tool from the water pump.

[g] Inspect the water pump cover seal for cracks or splitting. Refer to section 4.2.3.1.

[h] Install a new seal, if necessary, between the water pump cover and the water pump housing.

[i] Using snap ring pliers, install the water pump snap ring in groove of water pump body.

[j] Tap around the inside rim of snap ring with a brass drift, and hammer to seat snap ring in groove fully.

12. Check the bull gear-to-water pump drive gear lash measurement with water pump gear lash tool, J 38977-A, as follows:

[a] Remove the pipe plug in the gear case cover.

[b] Install the water pump gear lash tool, J 38977-A, through the hole in the gear case and thread it into the special water pump drive gear retaining bolt. See Figure 1-255.

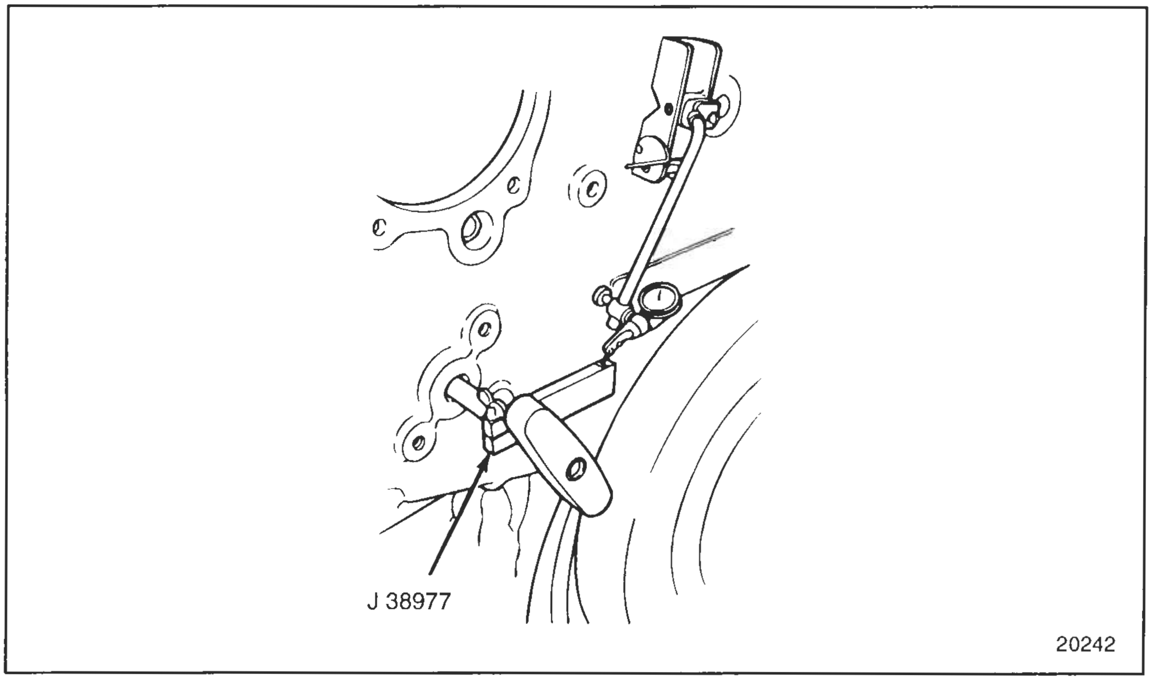


Figure 1-255 Water Pump Gear Lash Tool Method

[c] The arm of this tool has an inscribed line. Measuring with a dial indicator at this line of the tool, the gear lash measurement will be an exact 1:1 reading. Lash should be 0.051-0.229 mm (.002-.009 in.).

[d] If proper lash cannot be obtained, replace the gear with a new part.

[e] Remove the dial indicator and the gear lash tool.

[f] Install the pipe plug in the gear case cover. Torque to 24-31 N·m (18-23 lb·ft).

13. Check the bull gear–to–air compressor drive gear lash measurement as follows:
    - [a] Mount a magnetic dial indicator base and dial indicator to the gear case cover so that the stem of the dial indicator may be positioned on a tooth of the air compressor drive gear.
    - [b] Preload the drive gear in one direction.
    - [c] Zero the dial indicator.
    - [d] Rotate the air compressor drive gear, read and record the total gear lash. Lash should be 0.051–0.229 mm (.002–.009 in.) for new parts, with a maximum of 0.305 mm (.012 in.) for used gears.
    - [e] If proper lash cannot be obtained, replace the gear with a new part.
    - [f] Remove the dial indicator and magnetic base.
    - [g] Install the power steering drive coupling to the air compressor drive gear (if equipped with power steering).
    - [h] Insert a new O–ring on the power steering pump (if so equipped).
    - [i] Install the power steering pump to the gear case cover, meshing the drive coupling properly
    - [j] Install and tighten the power steering pump mounting bolts to 30–38 N·m (22–28 lb·ft) torque. Tighten the five bolts alternately and evenly, in a star–shaped pattern, to progressively draw the power steering pump into the gear case cover

NOTE:
Do not force the bolts. If resistance is encountered, remove the power steering pump and re–engage the drive hub with the coupling.

- [k] If the engine is not equipped with power steering, install the air compressor drive gear access cover using a new gasket.
- [l] Install and tighten the retaining bolts to 30–38 N·m (22–28 lb·ft) torque, using a star–shaped pattern.

1.21.3 Installation of Gear Train and Engine Timing

After all of the gear lash measurements have been taken, assemble the engine components as follows:

1. Install the air conditioner compressor and brackets (if so equipped). Install the air conditioner drive belt.
2. Install the alternator and brackets. Refer to OEM guidelines. Install the alternator drive belts.
3. Install the alternator drive belts. Refer to OEM guidelines.
4. Install the fan and fan hub assembly. Refer to section 4.5.5.
5. Adjust the alternator, fan and air conditioner compressor drive belts to the specifications. Refer to section 13.5.7. Torque the accessory mounting bolts to specifications.
6. Install any other equipment such as hoses, brackets, lines or electrical looms that were removed to gain access to the engine gear case cover.
7. Install the engine oil pan. Refer to section 3.9.3.
8. Fill the engine crankcase. Refer to section 13.5.1.
9. Continue engine assembly.

1.22 CAMSHAFT AND CAMSHAFT BEARING

The Series 50 Engines camshaft is located on top of the cylinder head, just below the valve cover. The camshaft actuates the intake and exhaust valves and injector operating mechanism. See Figure 1–256.

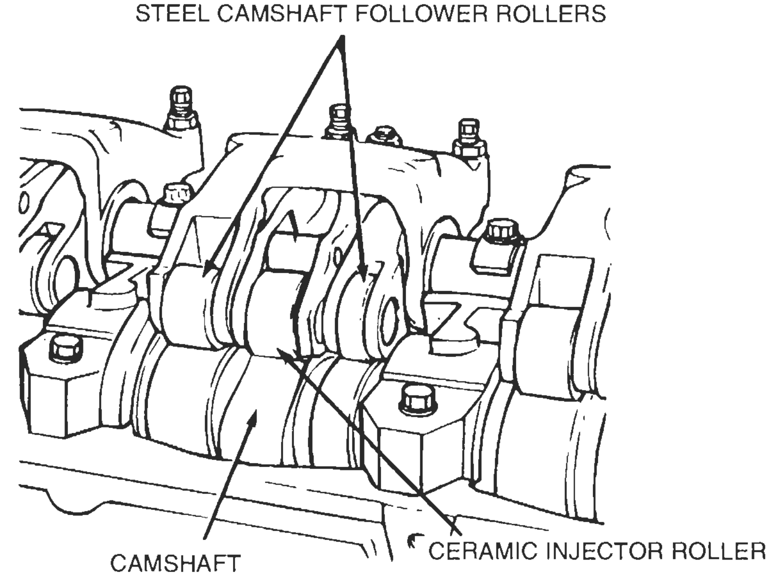
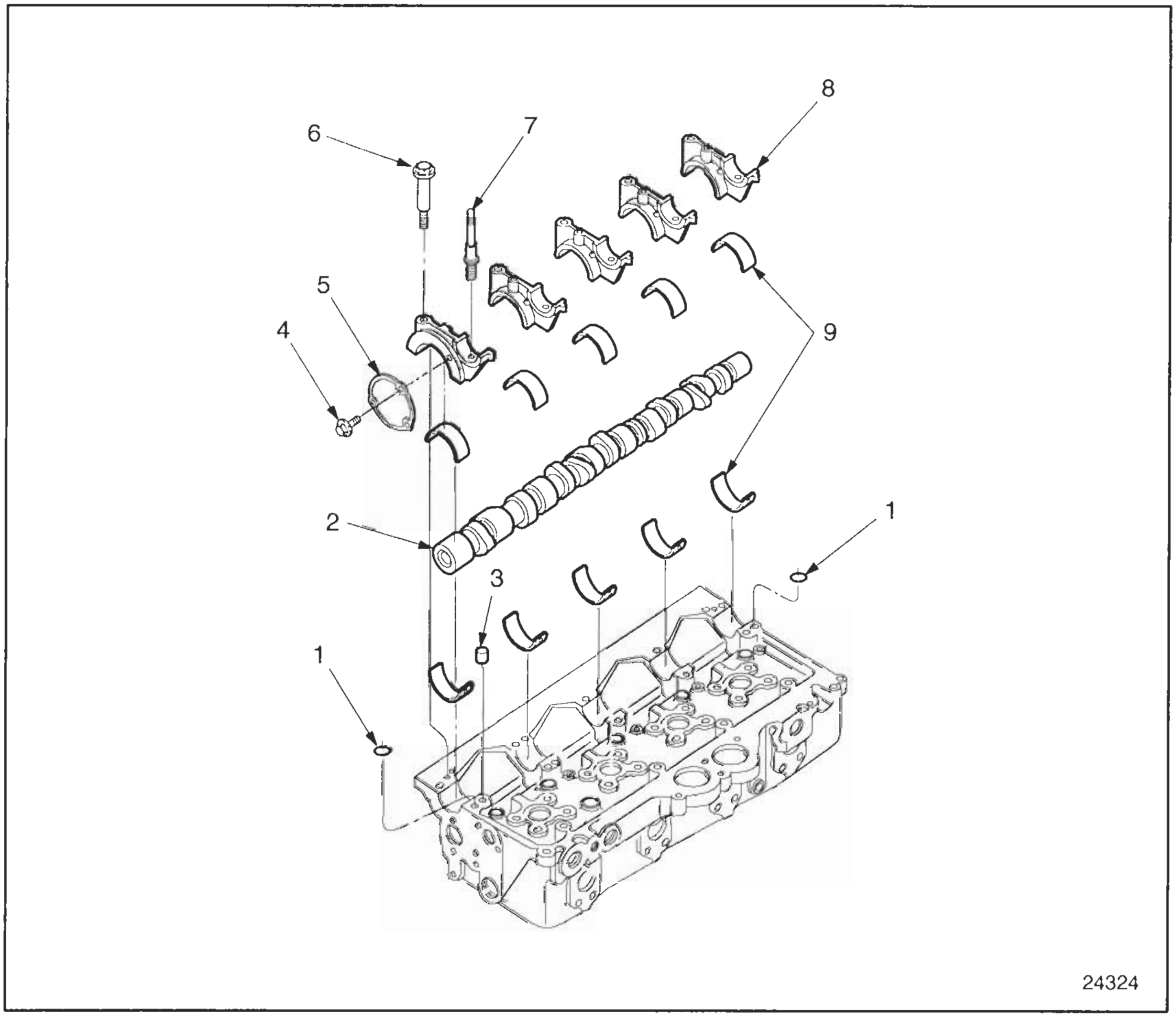


Figure 1–256 Camshaft and Related Parts

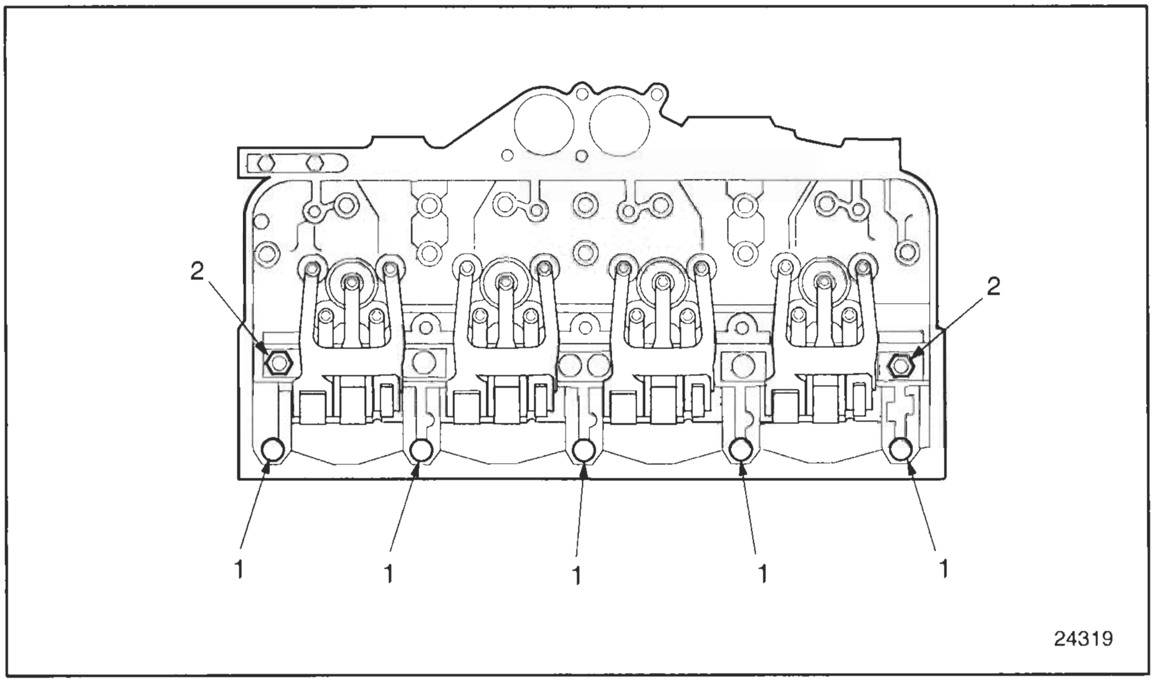
The camshaft is supported by five bearing assemblies, consisting of precision–type, replaceable bearing shell inserts that are split at their center lines. The lower bearing shell is positioned in a saddle that is integral with the cylinder head. The upper bearing shell is held in place by a machined camshaft cap. Upper and lower bearing shells are identical and have locating tangs and oil holes. Only the upper bearing shell oil holes index with oil supply holes in the camshaft caps. See Figure 1–257. These camshaft caps are precision line–bored after assembly to the cylinder head. Caps are NOT interchangeable once the head is finished. Caps are numbered and must NOT be interchanged with other caps of the same part number from stock or from a different cylinder head.



1. O–ring (2)
2. Camshaft
3. Dowel
4. Bolt, Camshaft Cover
5. Camshaft Cover
6. Bolt, Camshaft Cap (9)
7. Stud, Camshaft Cap (2)
8. Camshaft Cap
9. Bearing Shells

Figure 1–257 Camshaft Bearings and Caps

The No. 3 camshaft cap is secured to the cylinder head with three bolts, with No. 2, and 4 caps utilize two bolts each. Caps one and five have a stud and one bolt each. The stud and nut arrangement on the end caps (1 and 5) allows rocker arm shaft removal without disturbing the gasket eliminator seal from the end camshaft caps to the cylinder head. There are four different camshaft cap configurations. Only the intermediate caps No. 2, and 4 are identical but must not be interchanged during re-assembly. See Figure 1-258.



1. Camshaft Cap Bolt (5)
2. Camshaft Cap Stud and Nut (2)

Figure 1–258 Camshaft Caps Location

The camshaft is driven by a camshaft drive gear, located in the gear case at the front of the engine and is driven, through a series of intermediate gears, by the crankshaft timing gear. Refer to section 1.21 for gear train information and camshaft drive gear lash measurement and adjustment procedures. See Figure 1–259.

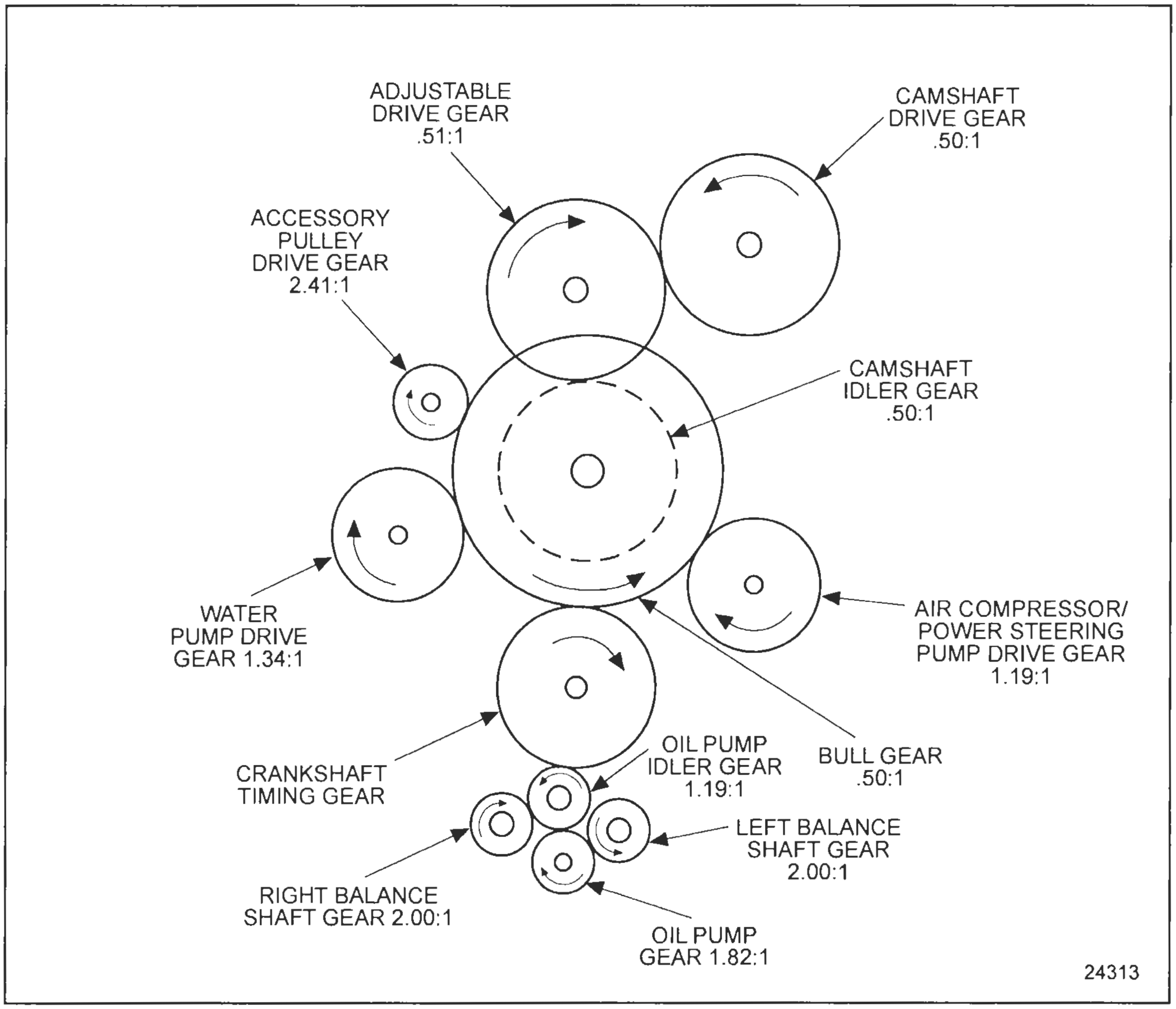
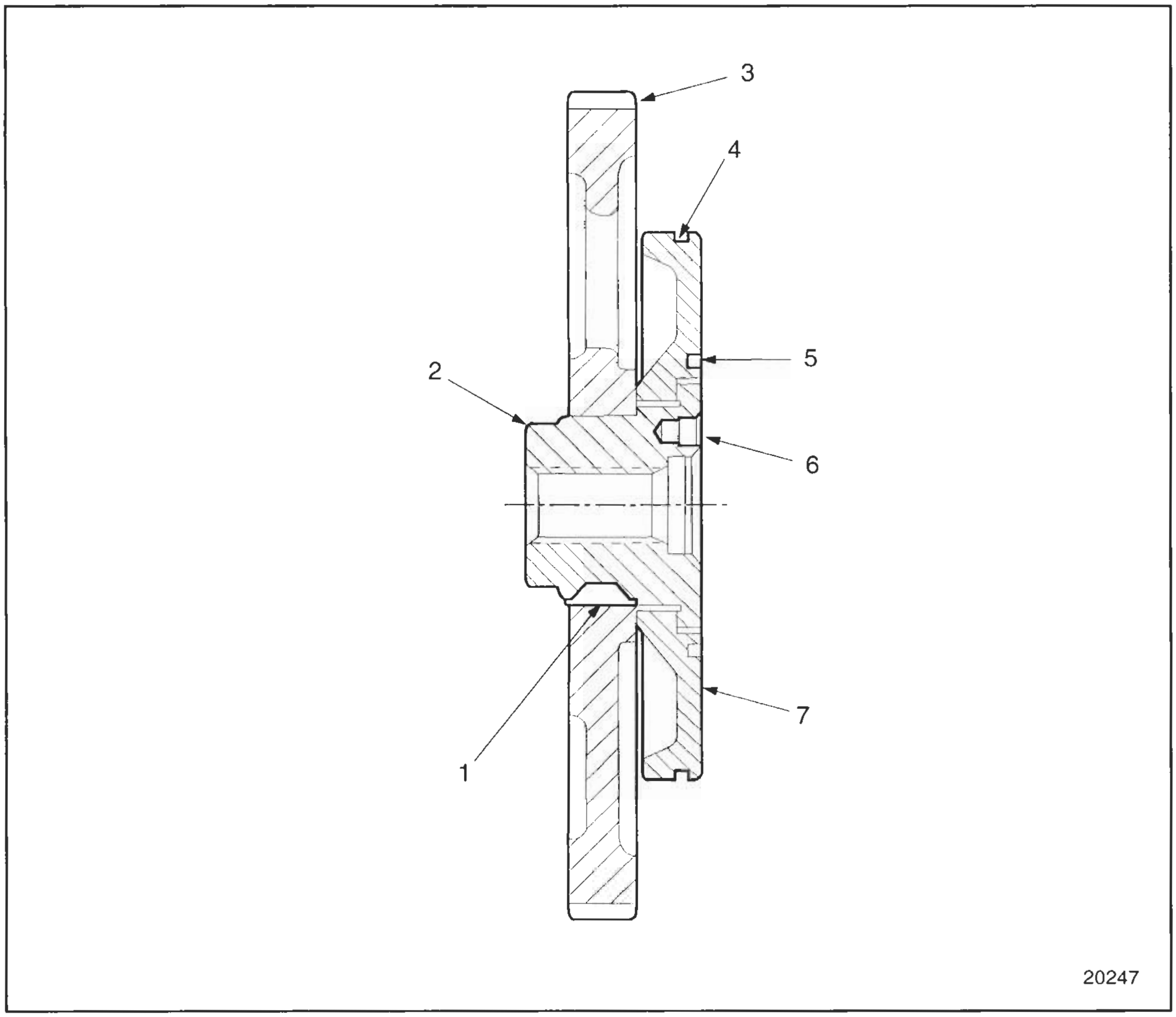


Figure 1–259 Engine Gear Train

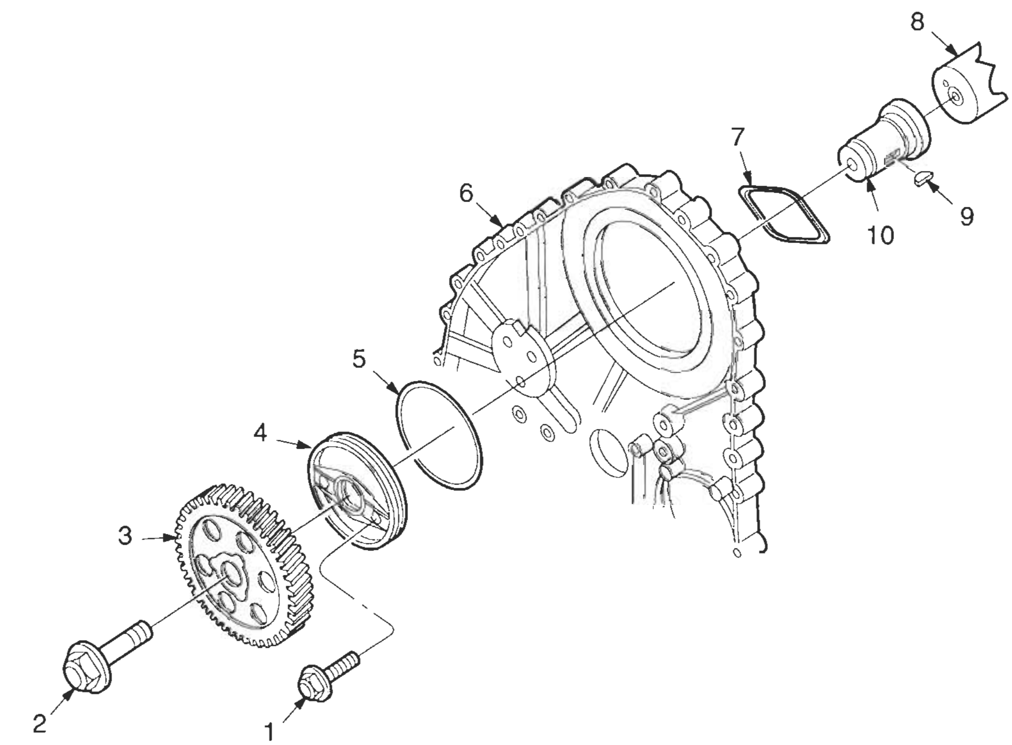
The camshaft drive gear is indexed to the camshaft drive gear hub by a Woodruff key and retained by a bolt which goes through the camshaft drive gear and hub and threads into the end of the camshaft. The camshaft has a dowel which indexes and fits into the mating hole in the camshaft hub. See Figure 1–260.



1. Woodruff Key
2. Camshaft Drive Gear Hub
3. Camshaft Drive Gear
4. O–ring Groove
5. Seal Groove
6. Camshaft Dowel Hole
7. Camshaft Thrust Plate

Figure 1–260 Cross–section of Camshaft Drive Gear and Related Parts

The camshaft hub is located in the camshaft thrust plate, which is positioned in an opening in the gear case housing. Refer to section 1.23.2 for camshaft drive gear, camshaft hub, or thrust plate removal. See Figure 1-261.



1. Bolt, Thrust Plate Retaining (2)
2. Bolt, Camshaft Hub Retaining
3. Drive Gear, Camshaft
4. Thrust Plate, Camshaft
5. O–ring
6. Gear Case
7. Seal, Thrust Plate
8. Camshaft
9. Key
10. Hub

Figure 1–261 Camshaft Thrust Plate and Related Parts

Access openings are provided in the gear case cover for camshaft drive gear lash adjustment and camshaft retaining bolt removal. See Figure 1–262.

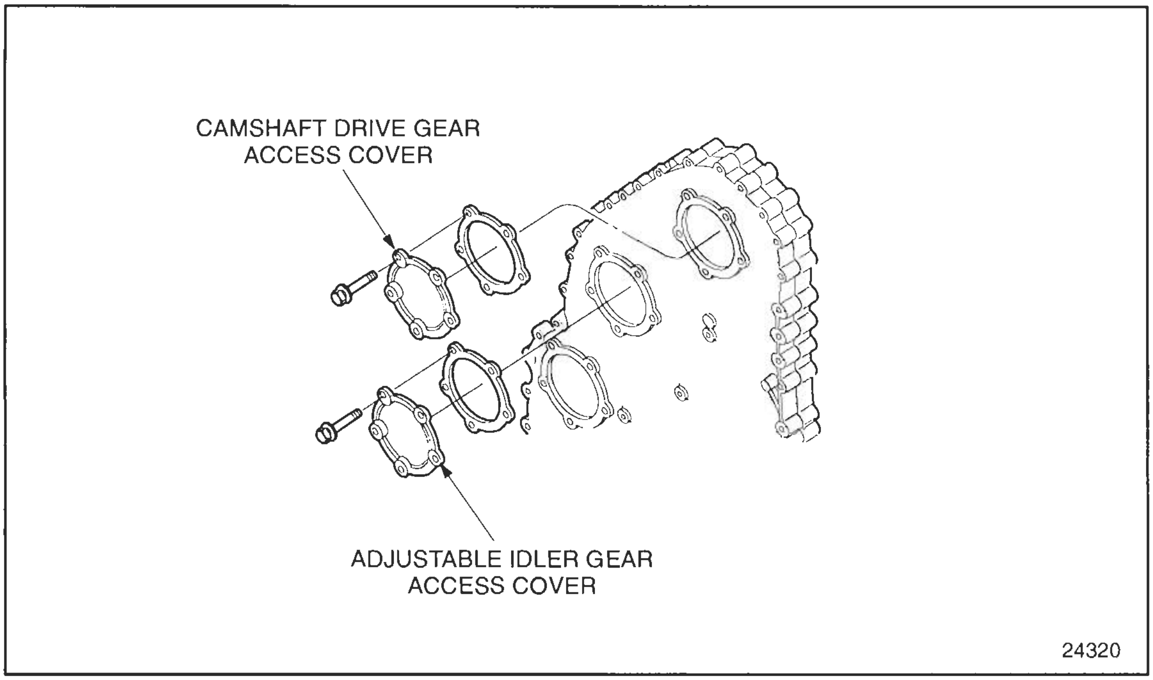


Figure 1–262 Camshaft Drive Gear and Adjustable Idler Gear Access Cover

A cover is provided at the rear end of the camshaft and is secured to the No. 5 camshaft bearing cap and the cylinder head by three bolts. See Figure 1–263.

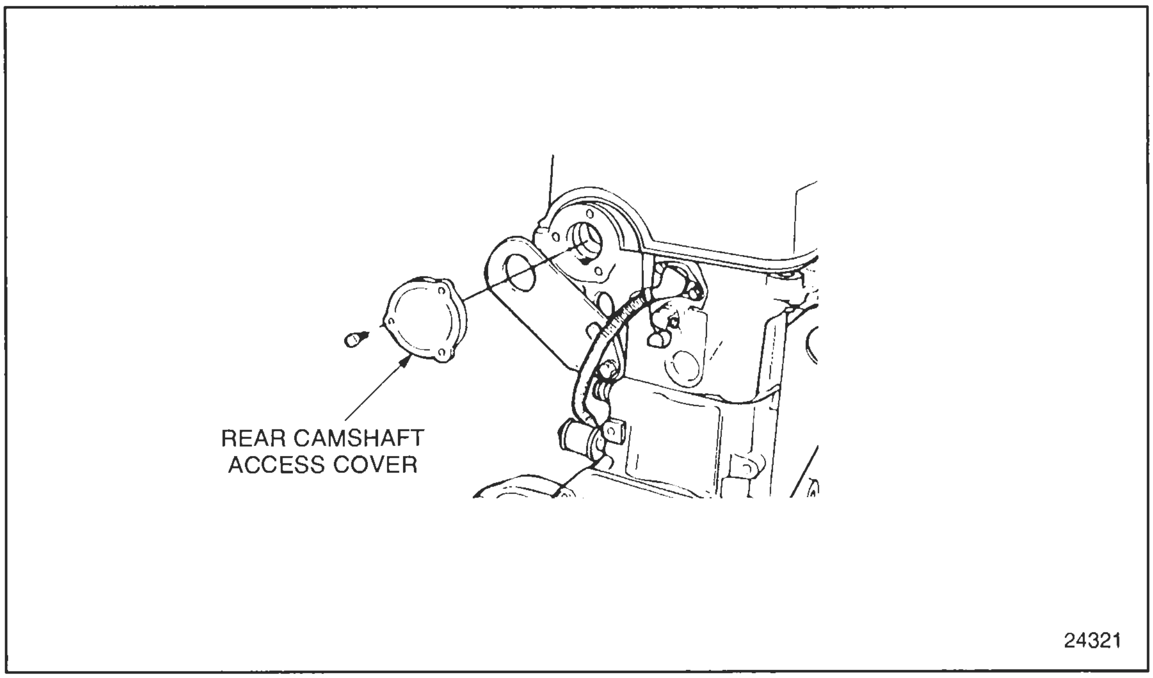
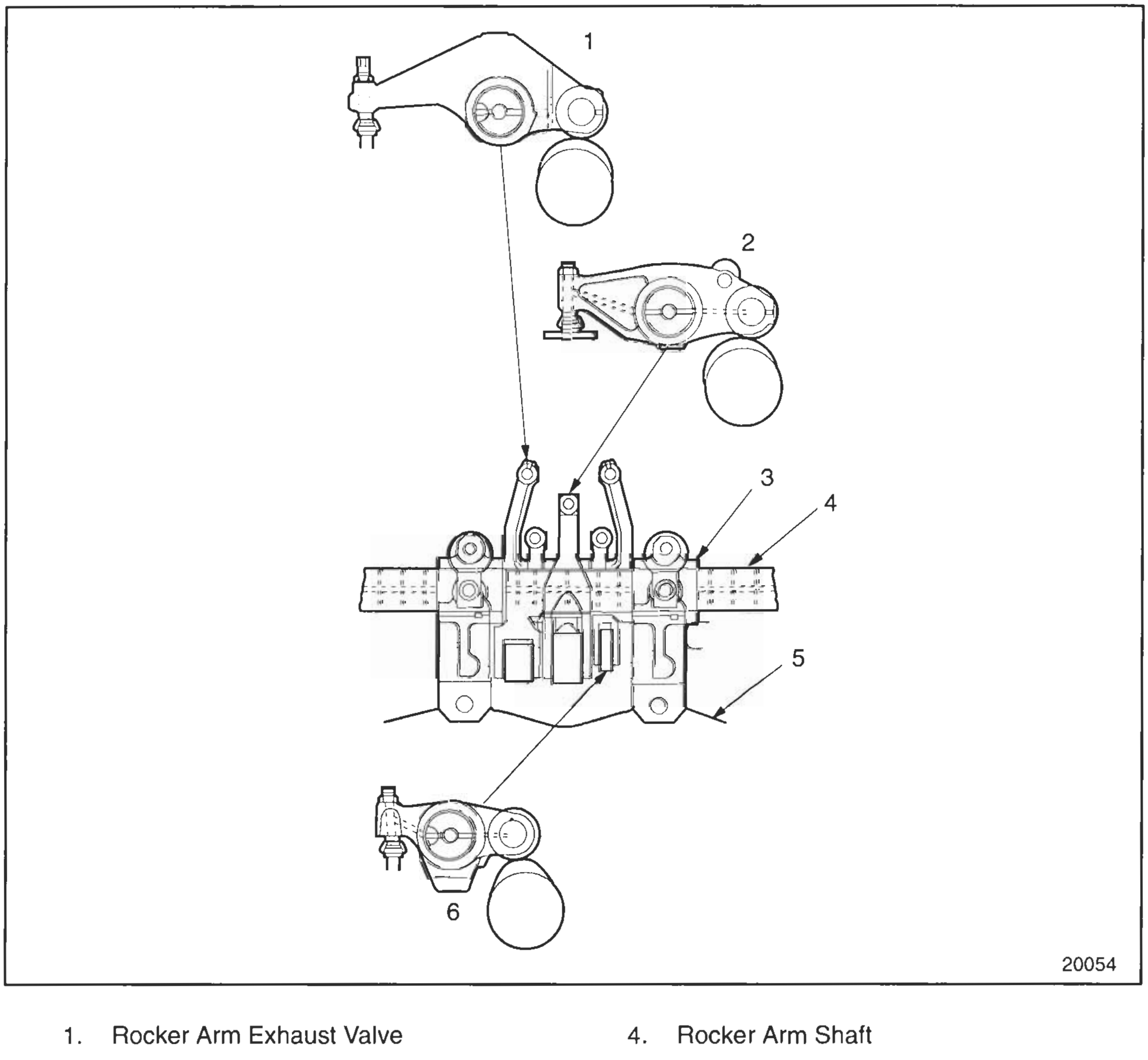


Figure 1–263 Rear Camshaft Access Cover

Vertical oil passages at the front and rear of the cylinder head deliver oil from the cylinder block front and rear oil galleries to the No. 1 and lower camshaft bearing saddles. From there, the oil is directed upward (through the enlarged stud hole) to the No. 1 and 5 upper bearing caps. A drilled passage in each of these caps exits at the rocker arm shaft seat area, where it indexes with a hole in each rocker arm shaft. The rocker arm shafts have internal oil passages that deliver oil to the rocker arm bushings and intermediate upper camshaft bearings. Some of the oil supplied to the rocker arm bushing passes through the oil hole in the bushing to the rocker arm. The rocker is drilled to supply oil to the camshaft follower, roller pin, and bushing. The rocker is also drilled to supply oil to the valve adjusting screw, valve button, retainer clip, intake, and exhaust valve stems and the fuel injector follower. The No. 3 camshaft cap is "Y" drilled, forming an oil path connection between the front and rear rocker arm shafts, to ensure complete lubrication. See Figure 1–264.



1. Rocker Arm Exhaust Valve
2. Rocker Arm Fuel Injector
3. Camshaft Cap
4. Rocker Arm Shaft
5. Cylinder Head
6. Rocker Arm, Intake Valve

Figure 1–264 Lubrication Schematic

1.22.1 Repair or Replacement of Camshaft and Camshaft Bearing

To determine if repair or replacement of the camshaft and camshaft bearings is necessary, perform the following procedure. See Figure 1-265.

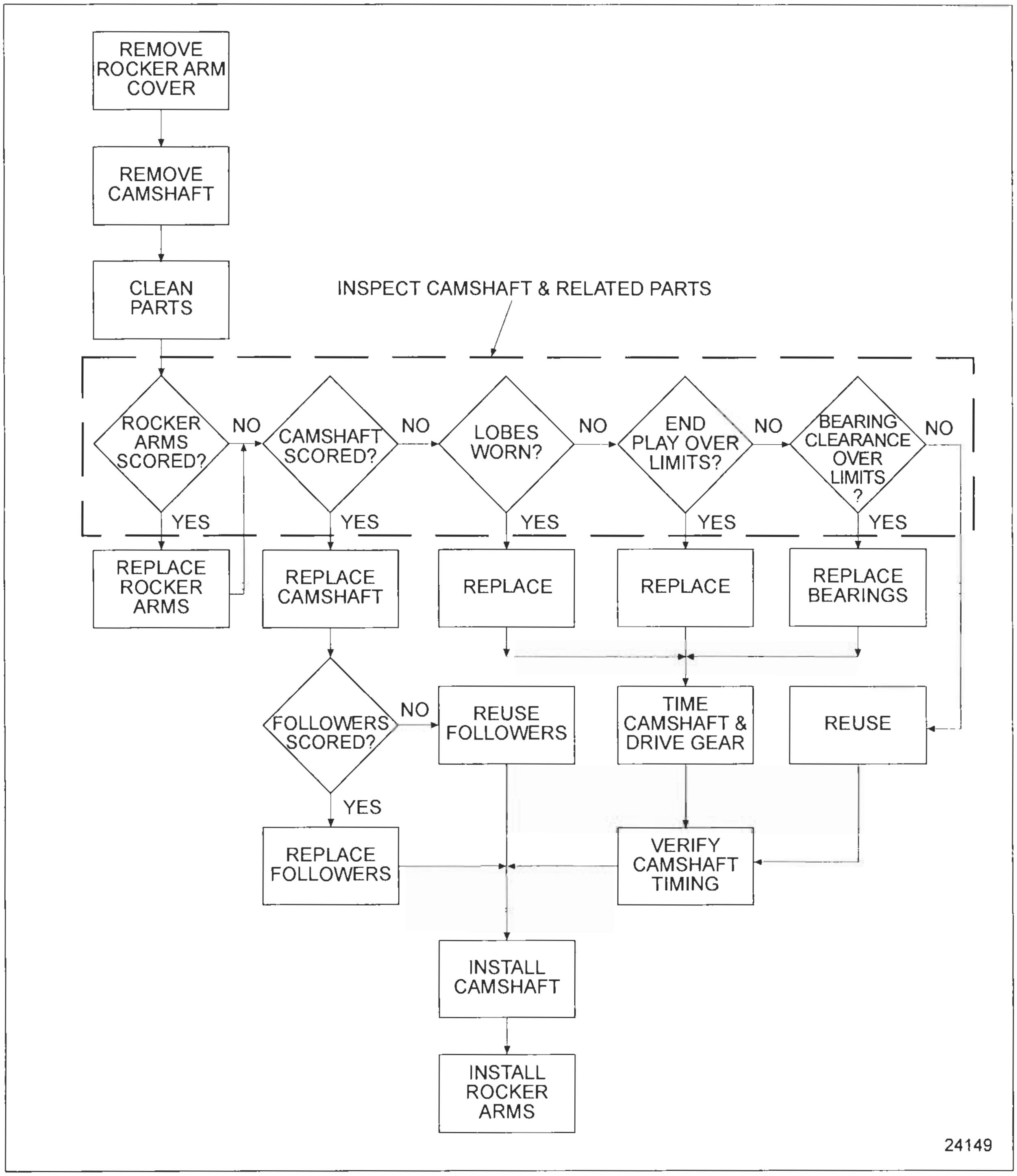


Figure 1–265 Flowchart for Repair or Replacement of Camshaft

1.22.2 Removal of Camshaft and Camshaft Bearing

Removal of camshaft and camshaft bearings as follows:

1. Remove the rocker cover. Refer to section 1.6.2.
2. Remove the five bolts that secure the camshaft drive gear access cover to the gear case. See Figure 1-262.
3. Remove both rocker arm shaft assemblies. Refer to section 1.3.2.

NOTICE:
Only special tool, J 35652–A, should be used to hold the camshaft drive gear stationary while loosening or tightening the camshaft drive gear–to–camshaft bolt. Other tools or devices can cause engine damage.

4. Insert the shoe of the camshaft drive gear torque holding tool, J 35652-A, through a lightening hole of the camshaft drive gear.
5. Bar the engine over slightly to position the camshaft drive gear holding tool so that the bolt holes in the holding tool align with the access cover bolt holes in the gear case cover. Using the 3/4 in. square hole in the center of the crankshaft pulley.
6. Install the camshaft drive gear torque holding tool, J 35652-A to the gear case, engaging one of the lightening holes in the camshaft drive gear. Use two of the access cover bolts to secure the tool to the gear case. See Figure 1-266.
7. Use a long 3/4 in. drive breaker bar and a 27 mm impact socket to remove the camshaft drive gear-to-camshaft bolt.

8. Remove the camshaft drive gear torque holding tool from the gear case.

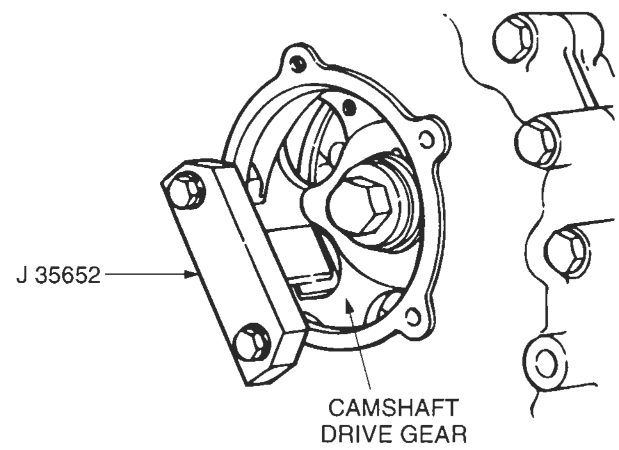


Figure 1–266 Camshaft Drive Gear Torque Holding Tool Installation

9. Rotate the crankshaft, using the square hole in the middle of the crankshaft pulley, to align the lightening holes in the camshaft drive gear to the camshaft thrust plate mounting bolts.

10. Remove the two camshaft thrust plate mounting bolts carefully, to avoid dropping them into the gear case. See Figure 1-267.

NOTE:
A clean shop towel may be inserted into the gear case opening to trap the bolts in case they are dropped. Do not allow the shop towel to drop into the gear case.

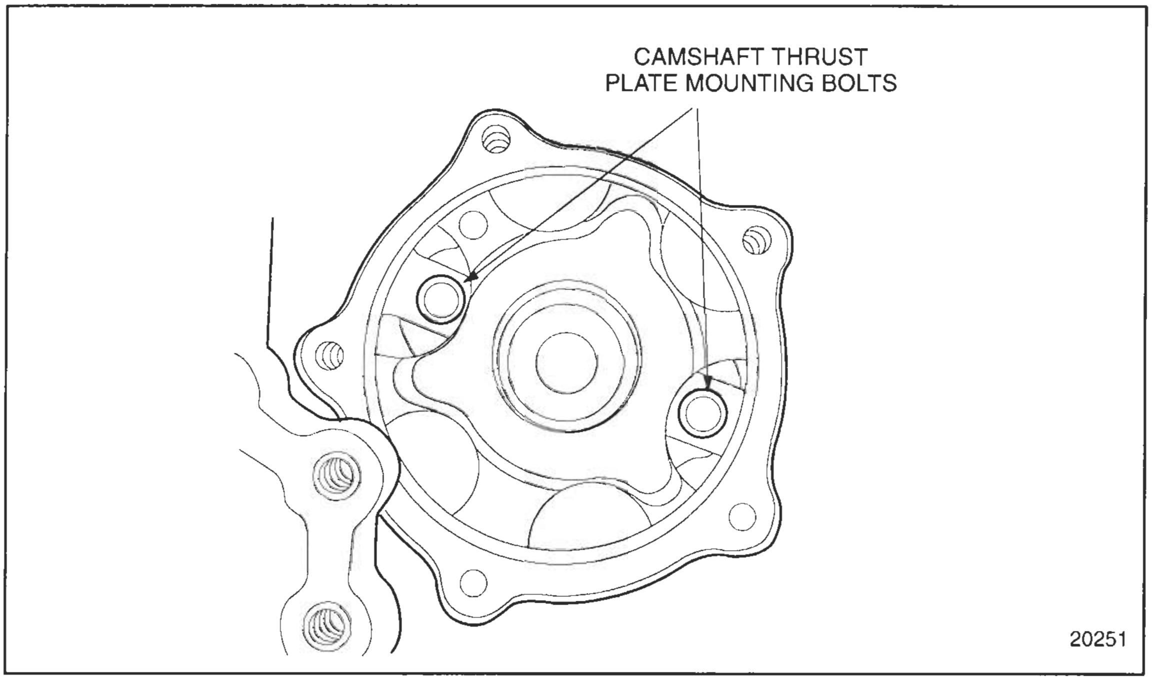


Figure 1–267 Camshaft Thrust Plate Bolts

11. Install the camshaft gear pilot, J 35906, to the camshaft drive gear access opening, using three of the access cover bolt holes. Engage the puller screw in the threads of the camshaft drive gear hub, until the screw is tight. See Figure 1–268.

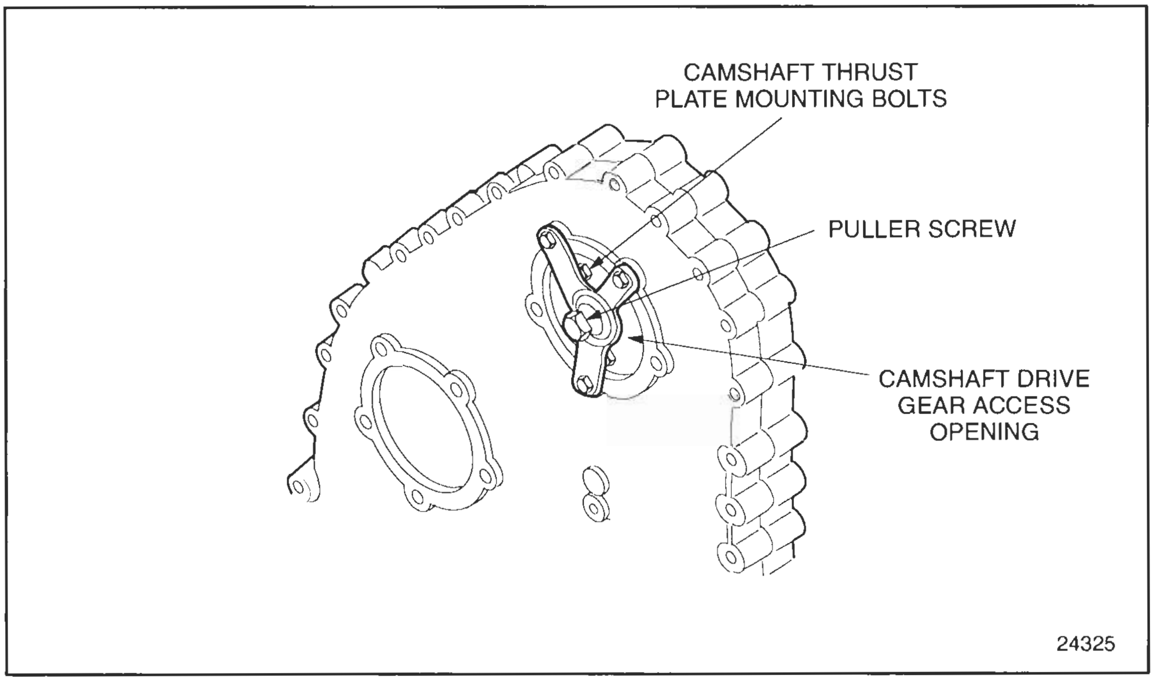


Figure 1–268 Camshaft Gear Pilot

12. Continue turning the puller screw to pull the camshaft drive gear hub and thrust plate forward approximately 6–7 mm (1/4 in.) until the thrust plate seal is clear of the camshaft front bearing cap and cylinder head. See Figure 1–269.

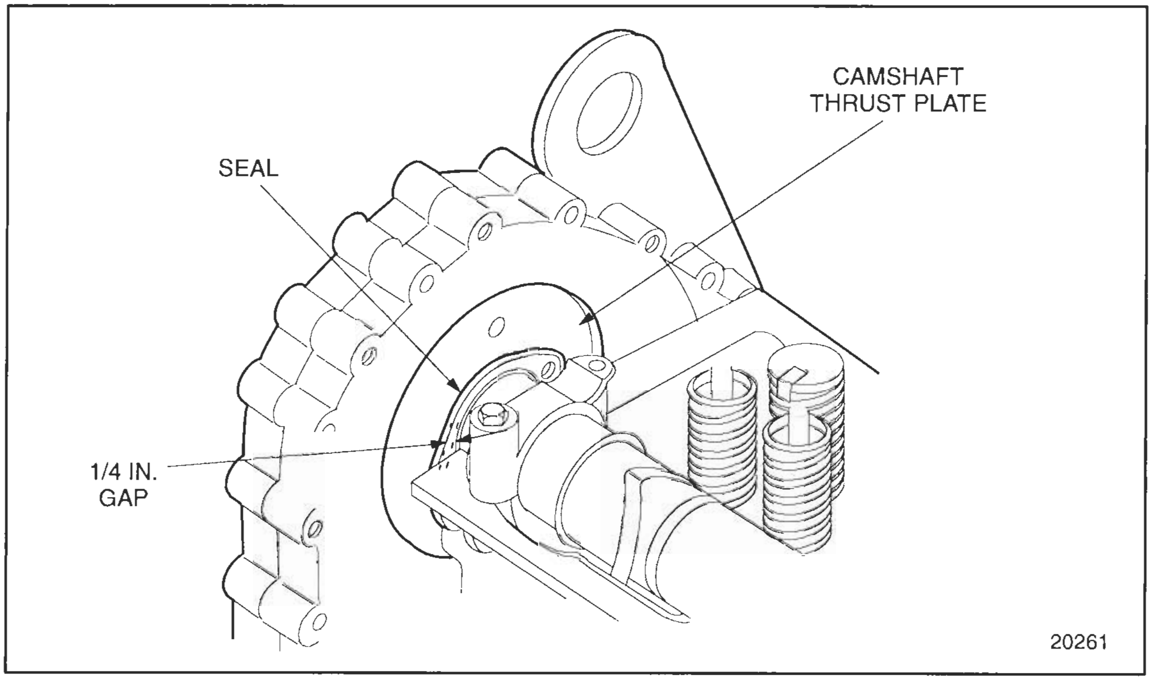


Figure 1–269 Camshaft Thrust Plate Clearance

13. Remove the three bolts that secure the rear camshaft cover to the engine and remove the cover.

14. Remove the remaining seven camshaft cap bolts. Remove the No. 1 and 5 studs using socket tool J 36003–A. See Figure 1–270.

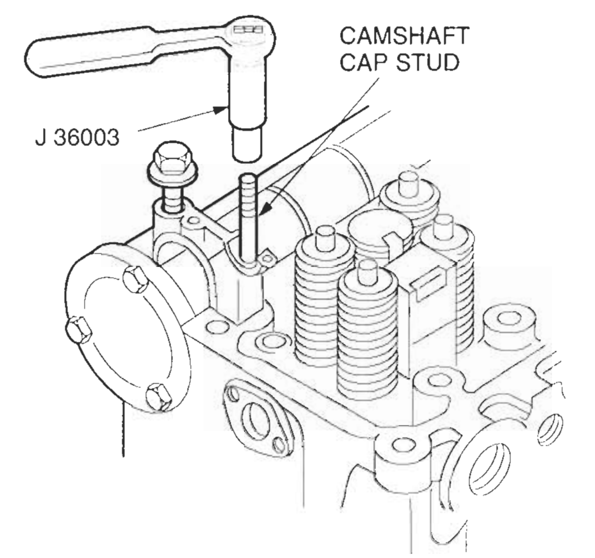


Figure 1–270 Camshaft Cap Stud Removal

15. Remove the seven camshaft bearing caps and the upper bearing shells. Keep the caps and shells together for possible later installation. Tag the bearing cap location, as they must always be installed in the same location.
16. Remove the center screw from the camshaft gear pilot tool. The camshaft gear pilot tool will remain in place, holding the camshaft drive gear in contact with the adjustable idler gear, to prevent accidental disengagement. This arrangement makes it unnecessary to retime the gear train.

NOTE:
The camshaft gear can go out of time if the pilot tool is removed.

17. Slide the camshaft rearward to completely disengage the dowel from the hub. Lift out the camshaft.
18. Remove the lower camshaft bearing shells, and group them with the upper shells and caps for possible reuse.

1.22.3 Disassembly of Camshaft and Camshaft Bearing

Refer to section 1.23.2 for disassembly of camshaft drive gear, camshaft hub and thrust plate assembly.

NOTE:
Disassembly of camshaft and drive gear assembly is not required for inspection. Disassembly will require timing of the camshaft gear again.

1.22.3.1 Inspection of Camshaft and Camshaft Bearing

Inspect camshaft and camshaft bearings as follows:

1. Clean all of the removed parts in clean fuel oil.
2. Ensure all oil passages are clear.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

3. Dry with compressed air.
4. Inspect the rocker arm components for scoring. Refer to section 1.4.5.3.
5. Replace damaged rocker arm components.

6. Inspect the camshaft lobes and journals for scoring, pitting, or flat spots.

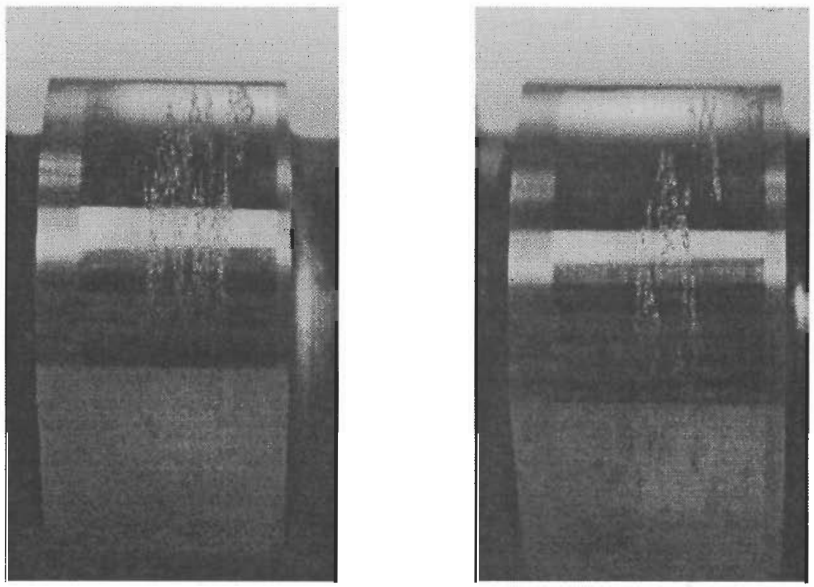


Figure 1–271 Camshafts Exhibiting Wear and Pitting

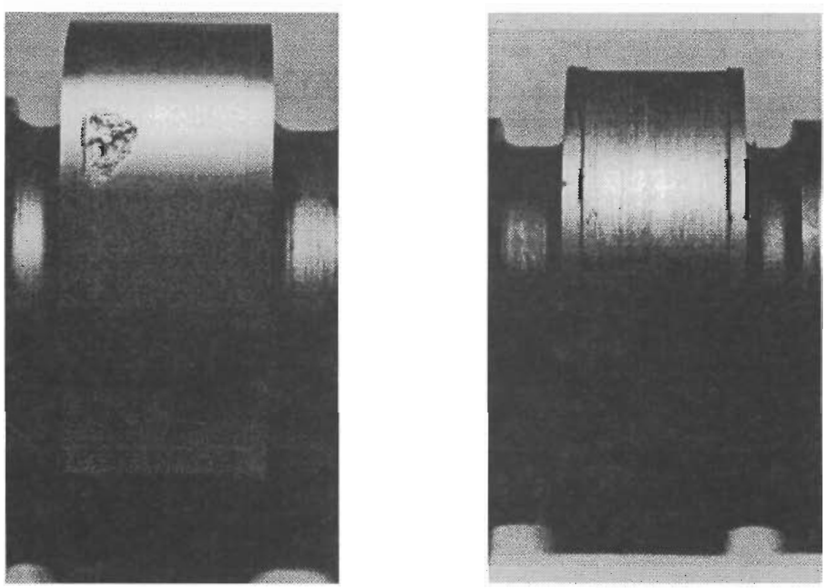


Figure 1–272 Camshafts Exhibiting Surface Pits on the Exhaust Lobes

NOTE:
Camshafts exhibiting extensive wear and pitting must be replaced. See Figure 1–271.

NOTE:
Camshafts may exhibit surface pits on the exhaust lobes. See Figure 1–272. Extensive durability and field testing has shown that surface pits on the exhaust lobes can occur early in the operation of the engine. These blemishes do not adversely affect engine performance or the durability of the camshaft and followers. Camshafts with this condition may be reused.

7. If the cam is scored, inspect the camshaft follower rollers.
8. Replace damaged camshaft followers.
9. If there is a doubt as to the acceptability of the camshaft for further service, determine the extent of camshaft lobe wear as follows:

NOTE:
The camshaft can be in or out of the engine during this procedure.

[a] With a set of feeler gages, 0.038–0.254 mm (.0015–.010 in.) and a piece of square, hard material 3 x 10 x 25mm (1/8 in. x 3/8 in. x 1 in.), measure the flat on the injector rise side of the camshaft lobes and nose of valve lobes. See Figure 1–273.

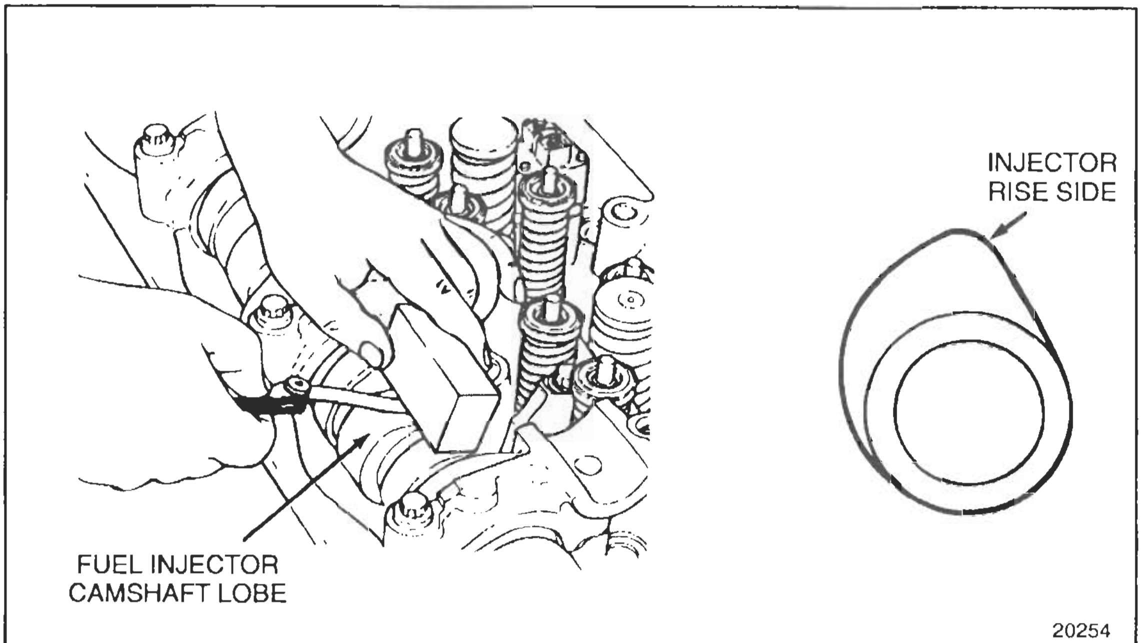


Figure 1–273 Checking Camshaft Lobe Wear

[b] If the flats measure greater than 0.076 mm (.003 in.) in depth and there are no other camshaft defects, replace the camshaft.

[c] Inspect the camshaft bearings for signs of excessive wear, scoring or pitting.

[d] Replace camshaft bearings as necessary.

NOTE:
If one camshaft bearing needs to be replaced, replace all of the camshaft bearing shells.

[e] Check the camshaft bearing clearance using plastic gaging material under each upper shell. See Figure 1–274.

NOTE:
Check camshaft bearing clearance with bearing shells, camshaft, bearing caps and rocker arm shafts (without rocker assemblies in place) installed, and cap bolts, studs and nuts tightened to specification.

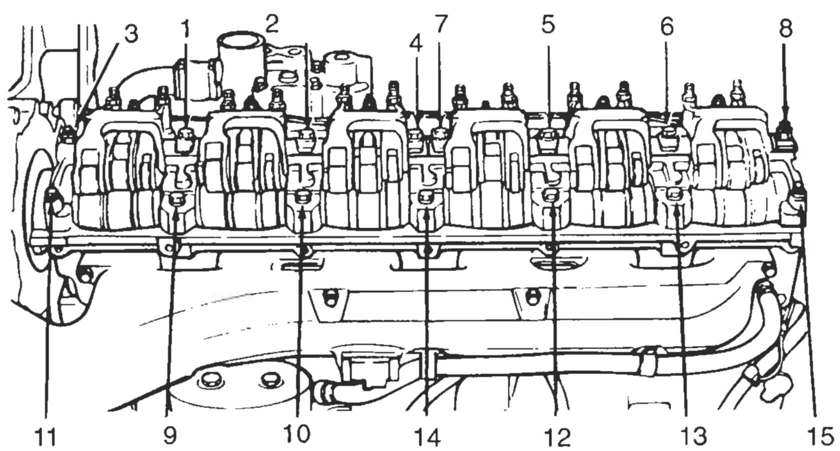


Figure 1–274 Camshaft Bearing Clearance Setup

[f] Allowable clearance is 0.09–0.166 mm (.0035–.0065 in.) or a maximum of 0.191 mm (.0075 in.) with used parts.

[g] Replace excessively worn or scored parts.

[h] After completing the camshaft bearing clearance measurements, remove the rocker arm shafts, bearing caps, camshaft, and camshaft bearings. Keep the caps and shells together for possible reuse.

[i] Clean all of the plastic gaging material from the bearing shells and camshaft journals if used parts are to be reused.

[j] Remove all of the Gasket Eliminator from both the cylinder head and camshaft caps.

[k] Coat the Nos. 1 and 5 bearing shell inserts with clean engine oil and install them to their respective locations in the cylinder head and camshaft caps.

[l] Install the camshaft to its normal position in the bearing saddles. Install the No. 1 and 5 camshaft caps to the cylinder head.

[m] Install the Nos. 1 and 5 camshaft cap outboard bolts and inboard studs and tighten both to 101–116 N·m (75–86 lb·ft) torque. Use tool J 36003-A to tighten the studs.

[n] Using a dial indicator with magnetic base, check the runout of the camshaft at the No. 3 bearing journal. See Figure 1-275.

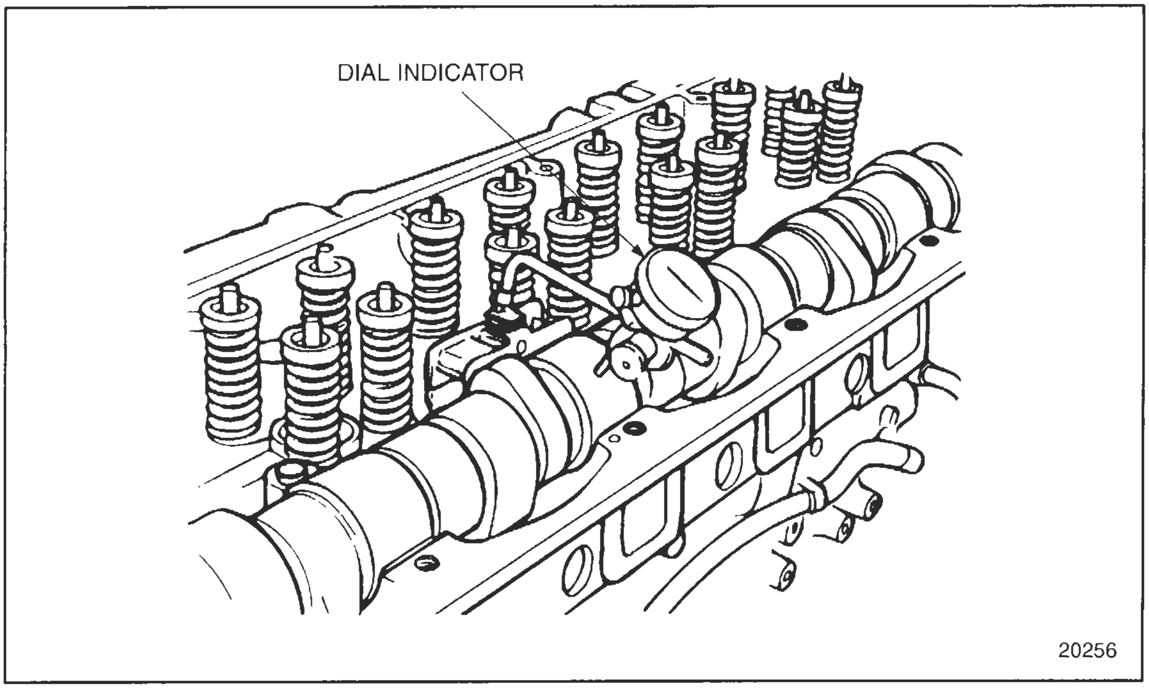


Figure 1–275 Camshaft Runout

[o] If camshaft runout exceeds 0.050 mm (.002 in.), replace the camshaft.

1.22.4 Assembly of Camshaft and Camshaft Bearings

Refer to section 1.23.3 for assembly of camshaft drive gear, camshaft hub and thrust plate assembly.

1.22.5 Installation of Camshaft and Camshaft Bearing

Install the camshaft and camshaft bearings as follows:

1. Coat the lower camshaft bearing shells with clean engine lubricating oil, and install them to their original positions. Note the position of oil holes and locating tangs.

NOTE:
If new bearings are to be installed, the upper and lower shells MUST be replaced as a set.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

2. When installing a new camshaft, steam clean it to remove the rust preventive and blow dry with compressed air.
3. Before installing the camshaft dowel into the camshaft hub, ensure that the dimple in the thrust plate is located at the 12 o'clock position to properly position bolt holes to cam cap and cylinder head. See Figure 1–276.

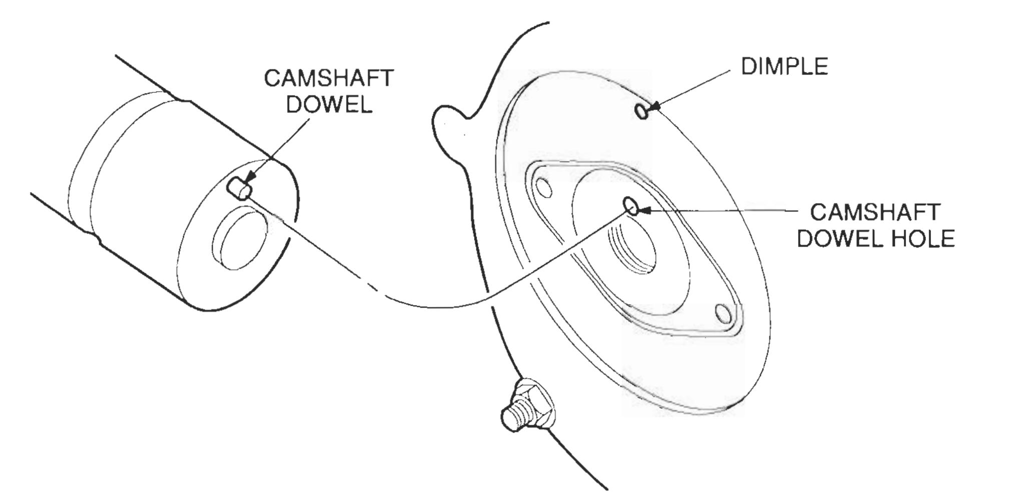


Figure 1–276 Indexing Camshaft Dowel

4. Coat the lobes and journals of the camshaft with clean engine lubricating oil. Index the dowel pin in the camshaft with the dowel hole in the camshaft hub.

5. Lower the camshaft into position and slide the camshaft forward, making certain that the camshaft dowel indexes with its mating hole in the camshaft thrust plate hub.
6. Install the upper bearing shells to the No. 1, 3 and 5 camshaft caps, noting the position of the oil holes and locating tangs.
7. Coat the bearing shells with clean engine lubricating oil.
8. Install the two rubber O-rings to the counterbores in the cylinder head at the No. 1 and 5 camshaft cap locations.

NOTICE:
Gasket Eliminator must be kept from the bearing shell sets and bearing surfaces. Gasket Eliminator cures with the absence of air. The length of time between installation of the No. 1 and 5 camshaft caps, and torquing the camshaft cap bolts and nuts should be kept to a minimum or improper lubrication will result causing engine damage.

9. Before assembling the camshaft caps to the cylinder head, ensure the two O-rings are in place on the cylinder head.
10. Apply a thin bead of gasket eliminator PT-7276, Loctite 51580 or equivalent to the joint face surfaces of the No. 1 and 5 camshaft caps. See Figure 1-277.

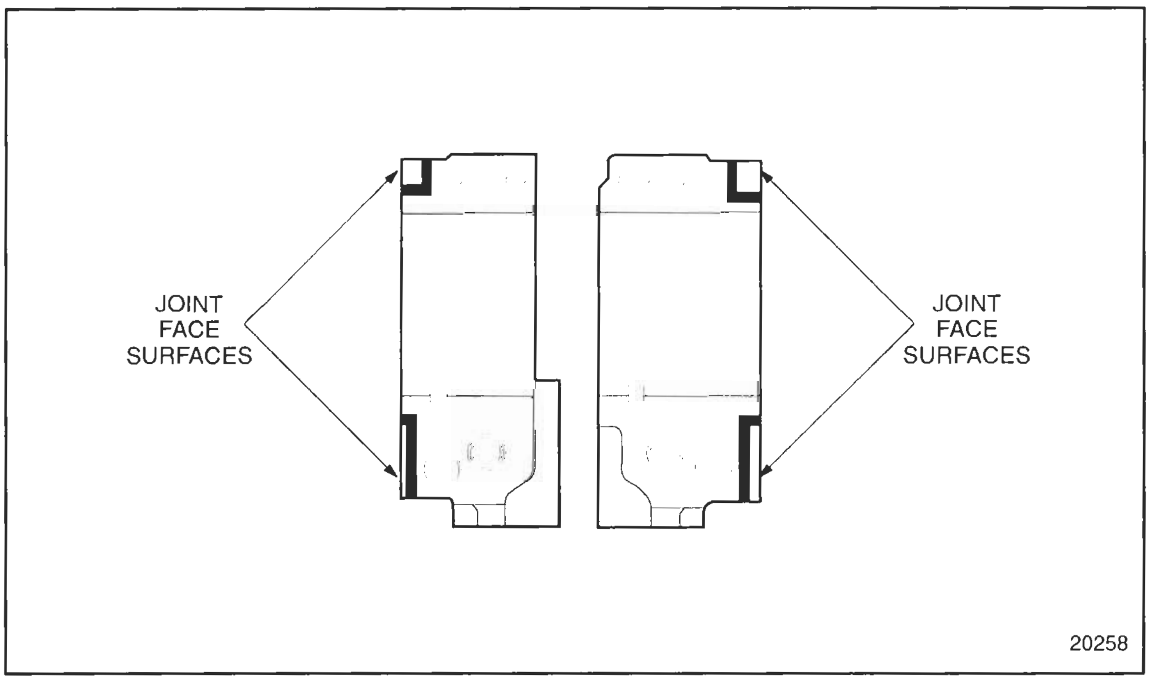


Figure 1-277 Gasket Eliminator Application

11. Install the No. 1, 3 and 5 camshaft caps, with bearing shells in place, to their respective locations.

12. Install and tighten the two inboard studs and outboard bolts on bearing caps No. 1 and 5 to 101–116 N·m (75–86 lb·ft) torque. Use tool J 36003–A to tighten the bearing cap studs.
13. Install the No. three bearing cap outboard bolt and tighten it to 101–116 N·m (75–86 lb·ft) torque.
14. Remove the three bolts holding the camshaft gear pilot, J 35906 to the gear case. Remove the camshaft gear pilot.

NOTICE:
Use care to ensure that the camshaft dowel is not disengaged during this step or damage to engine may result.

15. Working through the camshaft drive gear access hole in the front of the gear case, tap the center of the camshaft drive gear with a fiber mallet or plastic hammer to move the camshaft thrust plate, hub and camshaft drive gear rearward in the gear case until the camshaft thrust plate bolts can be started in the cylinder head and No. 1 camshaft cap.

NOTICE:
Using care to prevent dropping thrust plate mounting bolts into the gear case.

16. Install the thrust plate mounting bolts through the thrust plate and into the cylinder head and No. 1 camshaft cap. Using a 13 mm socket and ratchet, tighten the bolts alternately and progressively to draw the thrust plate straight into the gear case. Tighten the bolts to 30–38 N·m (22–28 lb·ft) torque.
17. Coat the threads and underside of the head of the camshaft drive gear–to–camshaft bolt with International Compound No. 2 (or equivalent). Install the bolt to the camshaft, finger tight.

NOTE:
The camshaft should be held in place while starting the camshaft drive gear–to–camshaft bolt, to prevent disengaging the camshaft dowel from the thrust plate hub and requiring disassembly and timing of camshaft.

18. Insert the shoe of the camshaft drive gear torque holding tool through a lightening hole of the camshaft drive gear.

NOTICE:
Only camshaft drive gear torque holding tool, J 35652–A should be used to hold the camshaft drive gear stationary while loosening or tightening the camshaft drive gear–to–camshaft bolt to prevent component damage.

19. Bar the engine over slightly to position the camshaft drive gear holding tool so that the bolt holes in the holding tool align with the access cover bolt holes in the gear case cover using the 3/4 in. square hole in the center of the crankshaft pulley to bar the engine over.
20. Install the two of the access cover bolts to secure the tool to the gear case.

NOTICE:
Failure to tighten the camshaft hub retaining bolt to the required torque may result in bolt loosening during engine operation, which may lead to camshaft alignment pin damage, altered engine timing, and erratic engine operation.

21. Using a 27 mm impact socket and suitable torque wrench, tighten the camshaft drive gear–to–camshaft bolt to 75 N·m (55 lb·ft) torque. See Figure 1–278.

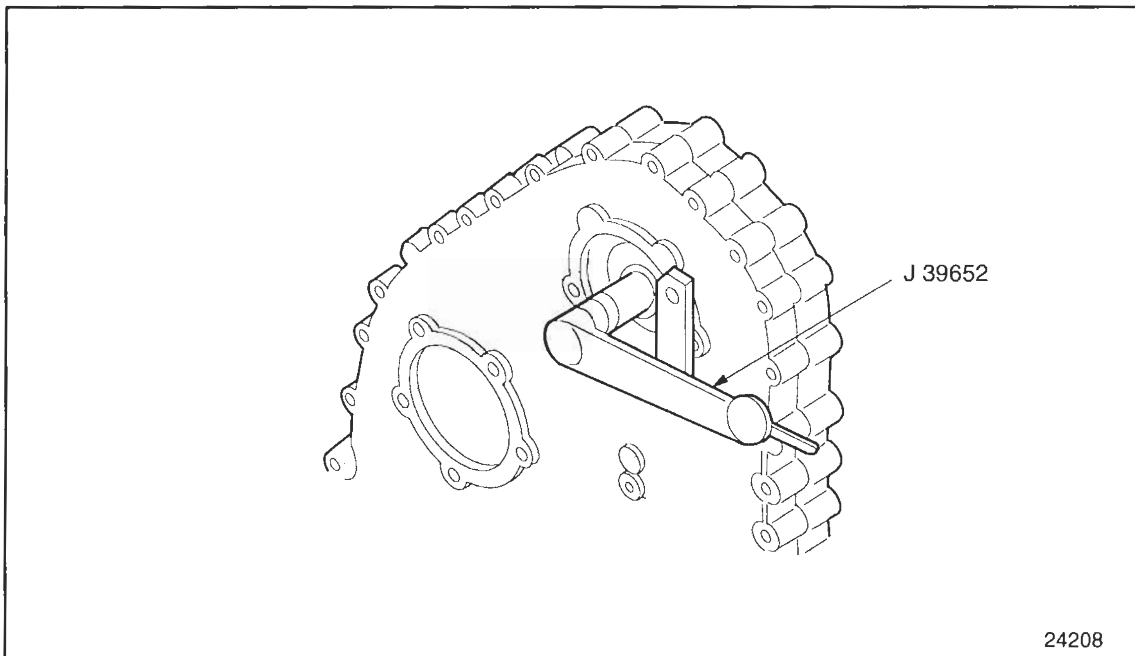


Figure 1–278 Camshaft Drive Gear–to–Camshaft Bolt Tightening

22. Turn the bolt an additional 90 degrees. See Figure 1–279.

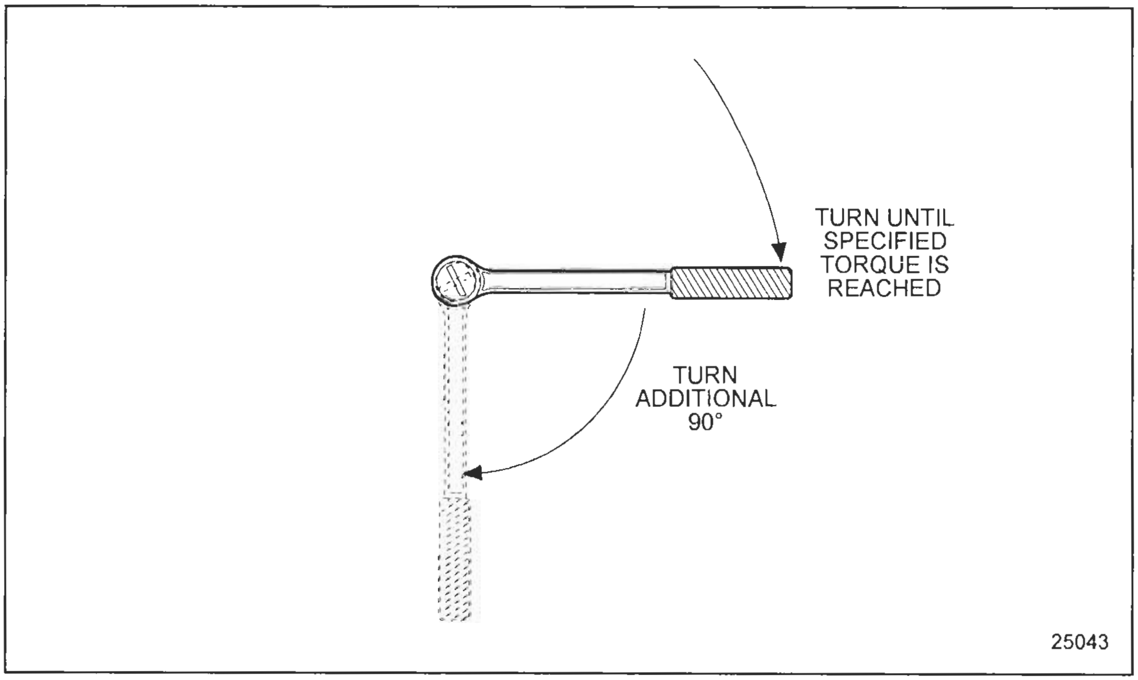


Figure 1–279 Torque Turn Limits

23. Remove the camshaft drive gear torque holding tool, J 35652–A.
24. Adjust the camshaft drive gear–to–adjustable idler gear lash. Refer to section 1.21.2.1.

NOTE:
Correct camshaft drive gear lash adjustment depends on the bolt and stud for No. 1 and 5 camshaft caps, the outboard bolt on No. 3 camshaft cap, and the camshaft drive gear–to–camshaft retaining bolt being tightened to the specified torque. However, the valve and injector spring pressures will not allow correct camshaft rotation. Therefore, do NOT install the rocker arm shaft assemblies before the camshaft gear lash has been measured and adjusted.

1.22.5.1 Test of Camshaft End–play

Measure the camshaft end–play, using a dial indicator and magnetic base, as follows:

1. Install the dial indicator so that the pointer is in contact with either the camshaft drive gear–to–camshaft retaining bolt, or at the rear end of the engine, in contact with the end of the camshaft. See Figure 1–280.

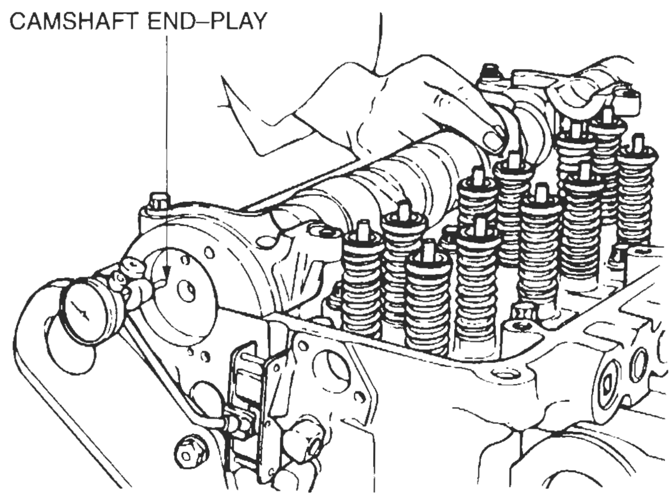


Figure 1–280 Camshaft End Play

2. Grasp the camshaft between the numbers one and three camshaft caps, and move the cam as far forward as possible. Zero the dial indicator.
3. Move the camshaft as far as possible, to the rear. Read and record the total amount of end–play as indicated.
4. Allowable camshaft end–play is 0.076–0.381 mm (.003–.015 in.).
5. If the end–play is beyond the maximum limit, loosen and retorque the camshaft drive gear–to–camshaft retaining bolt, and the camshaft thrust plate retaining bolts, to ensure that the camshaft thrust plate is seated properly in the gear case.
6. If the end–play is still beyond the maximum limit, remove and replace the camshaft thrust plate. Refer to section 1.23.2 and refer to section 1.23.3.

1.22.6 Installation of Camshaft and Camshaft Bearing

Continue installing camshaft and camshaft bearings as follows:

1. Install the bearing shells to the remaining No. 2 and 4 camshaft caps, noting the oil holes and locating tangs.
2. Coat the bearing shells with clean engine lubricating oil.
3. Install the remaining camshaft caps to their saddles on the cylinder head. Install the four outboard camshaft cap bolts for caps No. 2 and No. 4 finger tight.
4. If they were removed, install the adjusting screws, valve buttons and clips to the rocker arms.
5. Install the rocker arms to the rocker arm shafts in their original positions. Use the rocker arm identification marks to ensure correct component installation. See Figure 1-281.

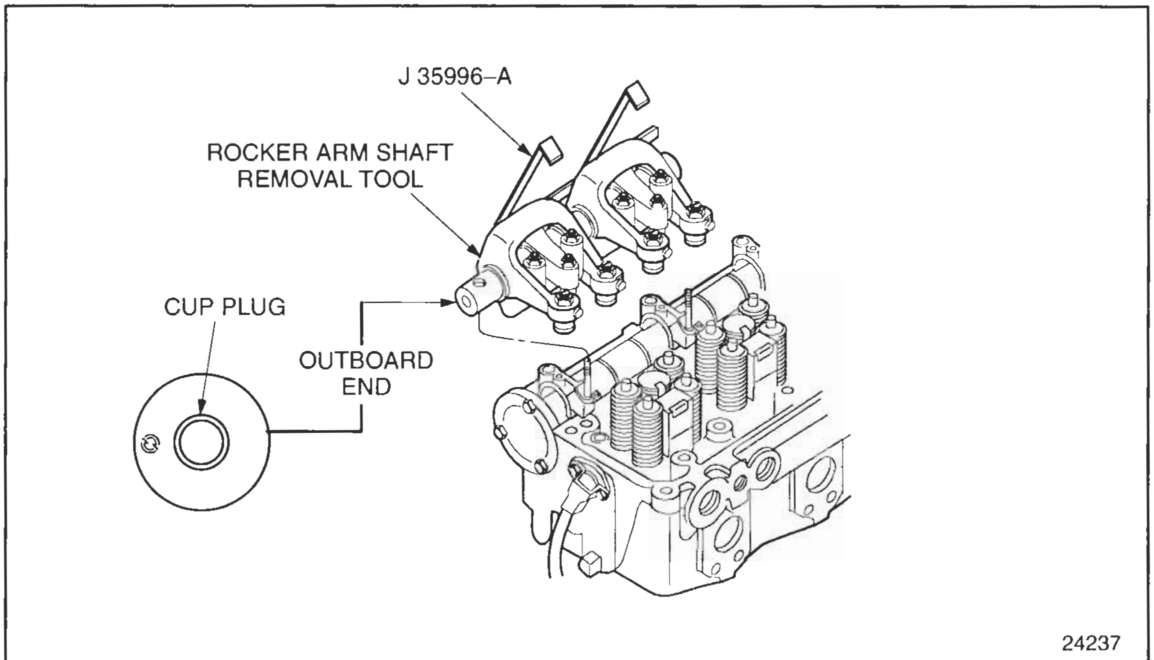


Figure 1–281 Rocker Arm Installation

6. Coat the rocker arm assemblies and camshaft liberally with clean engine lubricating oil.
7. Install the rocker arm shaft assemblies to the cylinder head. See Figure 1-281. Use care to locate the valve buttons to their respective valve stem and injector followers.
8. Install the remaining inboard camshaft cap bolts and spacers through the rocker arm shafts and into No. 2, 3, and 4 camshaft caps. Install the two nuts and spacers to the studs at No. 1 and No. 5 camshaft caps. Torque bolts to 101-116 N·m (75-85 lb·ft).

9. Tighten the 9 camshaft cap bolts and two nuts to 101–116 N·m (75–85 lb·ft) using the sequence. See Figure 1–282.

NOTE:
It is not necessary to tighten bolts 7 and 10, if a Jake Brake is to be installed.

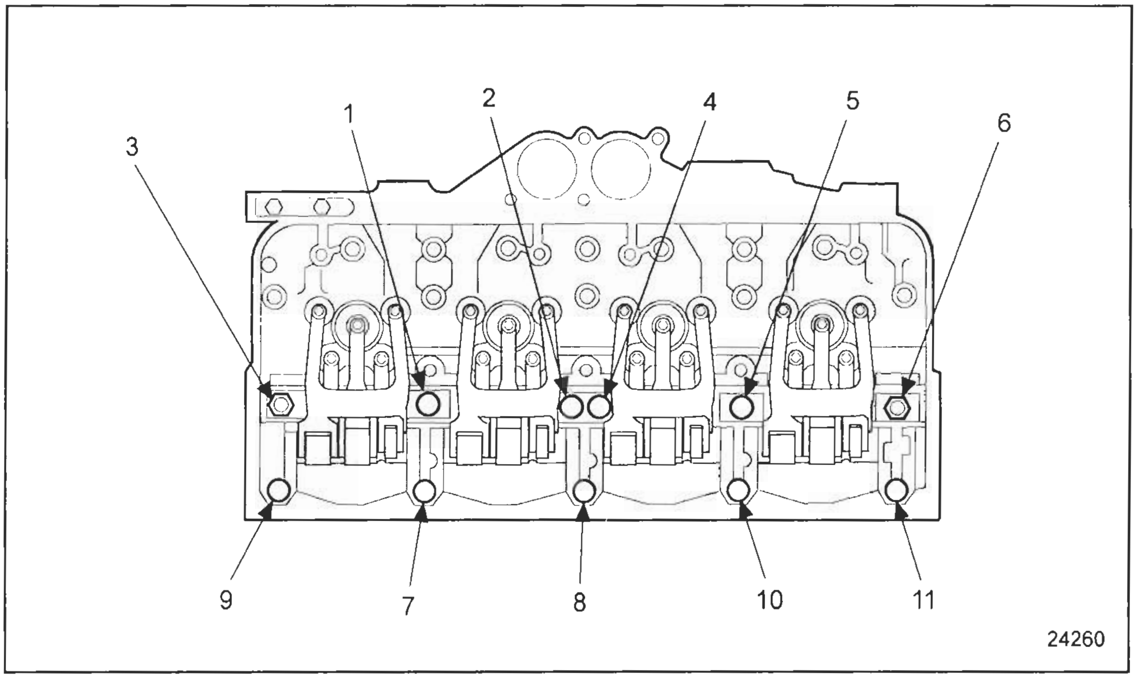


Figure 1–282 Camshaft Cap and Rocker Arm Shaft Bolt and Nut Torque Sequence

10. Clean all old gasket material from the mating surfaces of the rear camshaft cover and the cylinder head.
11. Apply a thin 1.5 mm (1/16 in.) bead of Gasket Eliminator, PT 7276 (Loctite 51580) or equivalent to the mating surface of the cover.
12. Install the cover and tighten the three bolts to 30–38 N·m (22–28 lb·ft) torque.
13. Clean all old gasket material from the mating faces of the camshaft drive gear access cover and the gear case cover.
14. Insert a new gasket between the camshaft drive gear access cover and the gear case.

15. Tighten the bolts to 30–38 N·m (22–28 lb·ft) using the tightening sequence. See Figure 1–283.

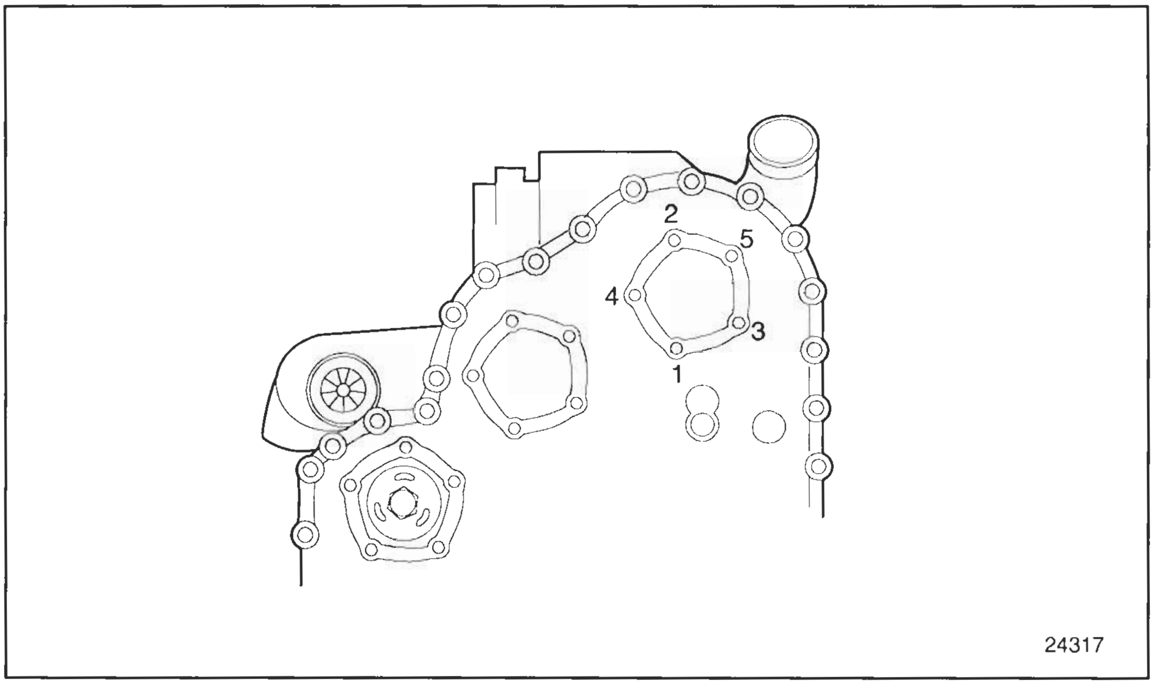


Figure 1–283 Camshaft Drive Gear Access Cover

16. Adjust the intake and exhaust valve clearances and set the injector heights. Refer to section 12.2.
17. Install the rocker cover. Refer to section 1.6.4.
18. Install the fan hub, refer to section 4.5.5., fan and drive belts. Refer to section 13.5.7.
19. Install any other components that were removed for this procedure.

1.22.6.1 Test of Camshaft Timing

Check the camshaft timing as follows:

NOTICE:
The camshaft must be in time with the crankshaft. An engine which is "out of time" may result in pre–ignition, uneven running or a loss of power.

1. Remove the rocker cover. Refer to section 1.6.2.
2. Select any cylinder for the timing check.
3. Remove the rocker arm assembly for the cylinder selected. Refer to section 1.3.2.
4. Remove the injector for that cylinder. Refer to section 2.2.2.
5. Carefully slide a rod, approximately 30 mm (12 in.) long, through the injector tube hole until the end of the rod rests on top of the piston.
6. Turn the crankshaft slowly in the direction of engine rotation. Stop when the rod reaches the end of its upward travel.

NOTE:
The cylinder selected must be on the compression stroke when performing this check.

7. Remove the rod and turn the crankshaft, opposite the direction of rotation, between 1/16 and 1/8 of a turn.
8. Select a dial indicator with 0.01 mm (.001 in.) graduations and a spindle movement of at least 25 mm (1 in.). Provide an extension for the indicator spindle. The extension must be long enough to contact the piston just before it reaches the end of its upward stroke.
9. Install a magnetic dial indicator base in a suitable place on the cylinder head and position the dial indicator over the injector hole tube.
10. Attach a suitable pointer to the gear case cover. The outer end of the pointer should extend over the vibration damper.
11. Turn the crankshaft slowly in the direction of engine rotation until the indicator hand just stops moving. Continue turning the crankshaft until the indicator hand starts to move again.
12. Reset the dial to zero.
13. Turn the crankshaft until the indicator reading is 0.25 mm (.010 in.).
14. Scribe a line on the vibration damper in line with the end of the pointer.
15. Slowly turn the crankshaft opposite the direction of engine rotation until the indicator hand just stops moving. Continue turning the crankshaft until the indicator hand starts to move again.

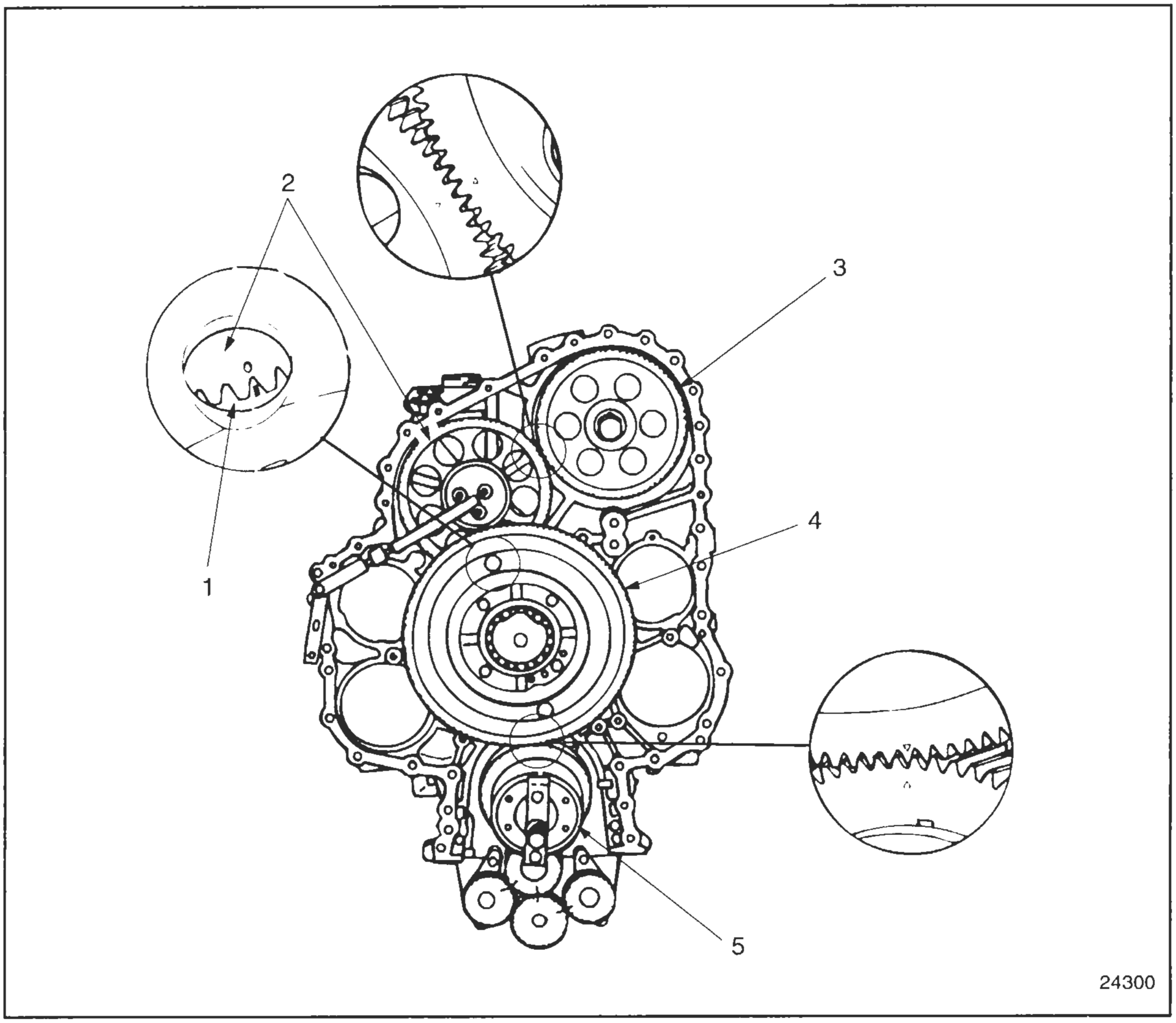
16. Reset the dial to zero.
17. Then turn the crankshaft in the same direction until the indicator reading is 0.25 mm (.010 in.).
18. Scribe a second line on the vibration damper in line with the end of the pointer.
19. Scribe a third line half way between the first two lines. This is top dead center for the cylinder selected when the pointer is lined up with it.
20. Remove the dial indicator and base from the engine.
21. Install the injector that was removed. Refer to section 2.2.5.
22. Install the overhead assembly. Refer to section 1.3.3.
23. Turn the crankshaft opposite the direction of engine rotation while watching the injector rocker arm cam follower for the cylinder selected. Turn the crankshaft until the cam follower is on the base circle of the injector lobe of the cam.
24. Install a magnetic dial indicator base on the cylinder head. Install a dial indicator so that the spindle rests directly on the injector cam follower roller for the cylinder selected.

NOTE:
The spindle should be on the center line of the injector cam follower roller pin in order to get an accurate measurement of cam lift.

25. Turn the crankshaft slowly, in the direction of engine rotation, until the center mark on the vibration damper lines up with the pointer.
26. The correct indicator reading is 4.39 mm (.173 in.) to 5.46 mm (.215 in.).
27. If the cam lift is incorrect, retime the engine. Refer to section 1.21.2.1.

1.23 CAMSHAFT DRIVE GEAR

The camshaft drive gear, located at the front of the engine, under the gear case cover, is driven by the crankshaft through a series of intermediate gears. See Figure 1-284.



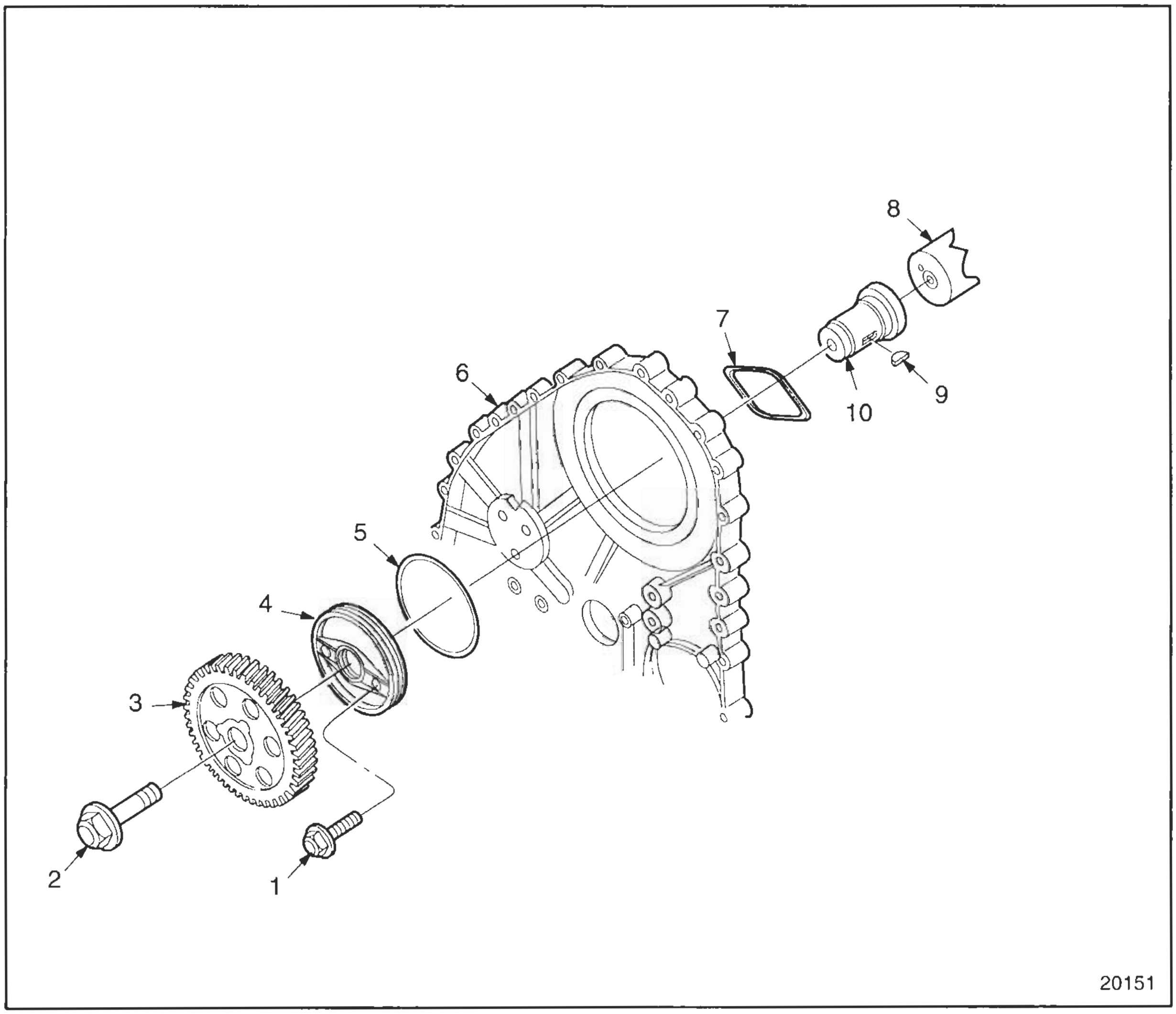
1. Idler Gear, Camshaft
2. Idler Gear, Adjustable
3. Drive Gear, Camshaft
4. Bull Gear
5. Timing Gear, Crankshaft

Figure 1–284 Engine Gear Train and Timing Marks

The gear train for the crankshaft drive consists of a crankshaft timing gear, mounted to the end of the crankshaft, meshing with a bull gear. To the rear of the bull gear is the camshaft idler gear, which is mounted on the same hub and rotates at the same speed as the bull gear. The camshaft idler gear meshes with an adjustable idler gear, which is mounted on a separate hub. The adjustable idler gear in turn meshes with the camshaft drive gear, which is mounted on the camshaft drive gear hub. The gears are designed so that the camshaft is driven at half crankshaft speed.

Since the camshaft must be timed exactly to the crankshaft, a series of timing marks are stamped or etched on the gear faces of these gears so that they may be installed in correct relationship to each other. Refer to section 1.21.2.1.

The camshaft drive gear is keyed and pressed onto a hub located in the thrust plate assembly at the end of the camshaft. The camshaft drive gear and hub are retained to the end of the camshaft by the camshaft drive gear retaining bolt which goes through the camshaft drive gear and the hub, and is threaded into the end of the camshaft. See Figure 1–285.



1. Bolt, Thrust Plate Retaining (2)
2. Bolt, Camshaft Hub Retaining
3. Drive Gear. Camshaft
4. Thrust Plate, Camshaft
5. O–ring
6. Gear Case
7. Seal, Thrust Plate
8. Camshaft
9. Key
10. Hub

Figure 1–285 Camshaft Drive Gear and Related Parts

The camshaft is indexed to the hub by a dowel. The camshaft drive gear hub rides in a camshaft thrust plate, which is retained by two bolts. One of these bolts screws into the cylinder head, while the other bolt screws into the No. one camshaft bearing cap.

The camshaft thrust plate is sealed to the gear case by an O–ring which fits into a groove machined in the outer diameter of the thrust plate. A diamond shaped rubber seal that fits into a groove machined in the rear camshaft thrust plate face, seals the camshaft thrust plate to the cylinder head and No. one camshaft cap. The dimple in the thrust plate must be installed at the 12 o'clock position to allow alignment of the thrust plate bolt holes with those in the cylinder head and No. 1 camshaft cap. See Figure 1–286.

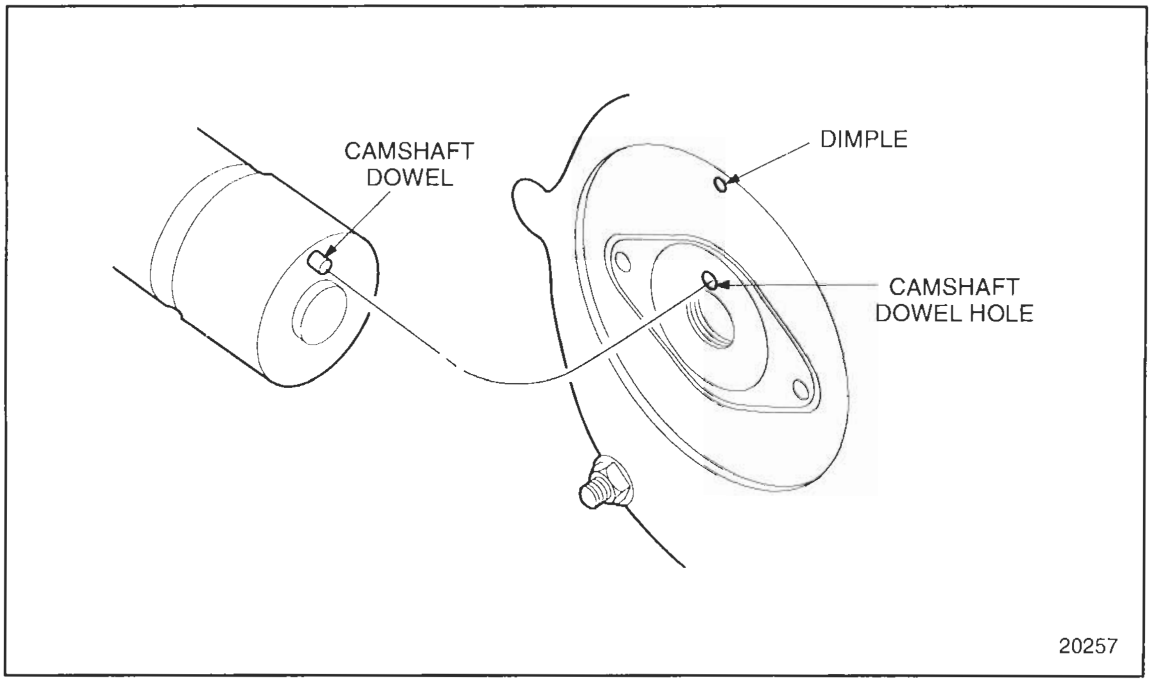


Figure 1–286 Camshaft Thrust Plate and Related Parts

The camshaft thrust plate can be moved horizontally in the gear case, to allow camshaft and cylinder head removal without damaging the thrust plate seal or removing the gear case cover. The camshaft drive gear will stay in mesh with its mating gear, and may be returned to its original position without retiming the gears.

1.23.1 Repair or Replacement of Camshaft Drive Gear

To determine if repair or replacement of the camshaft drive gear is necessary, preform the following procedure. See Figure 1–287.

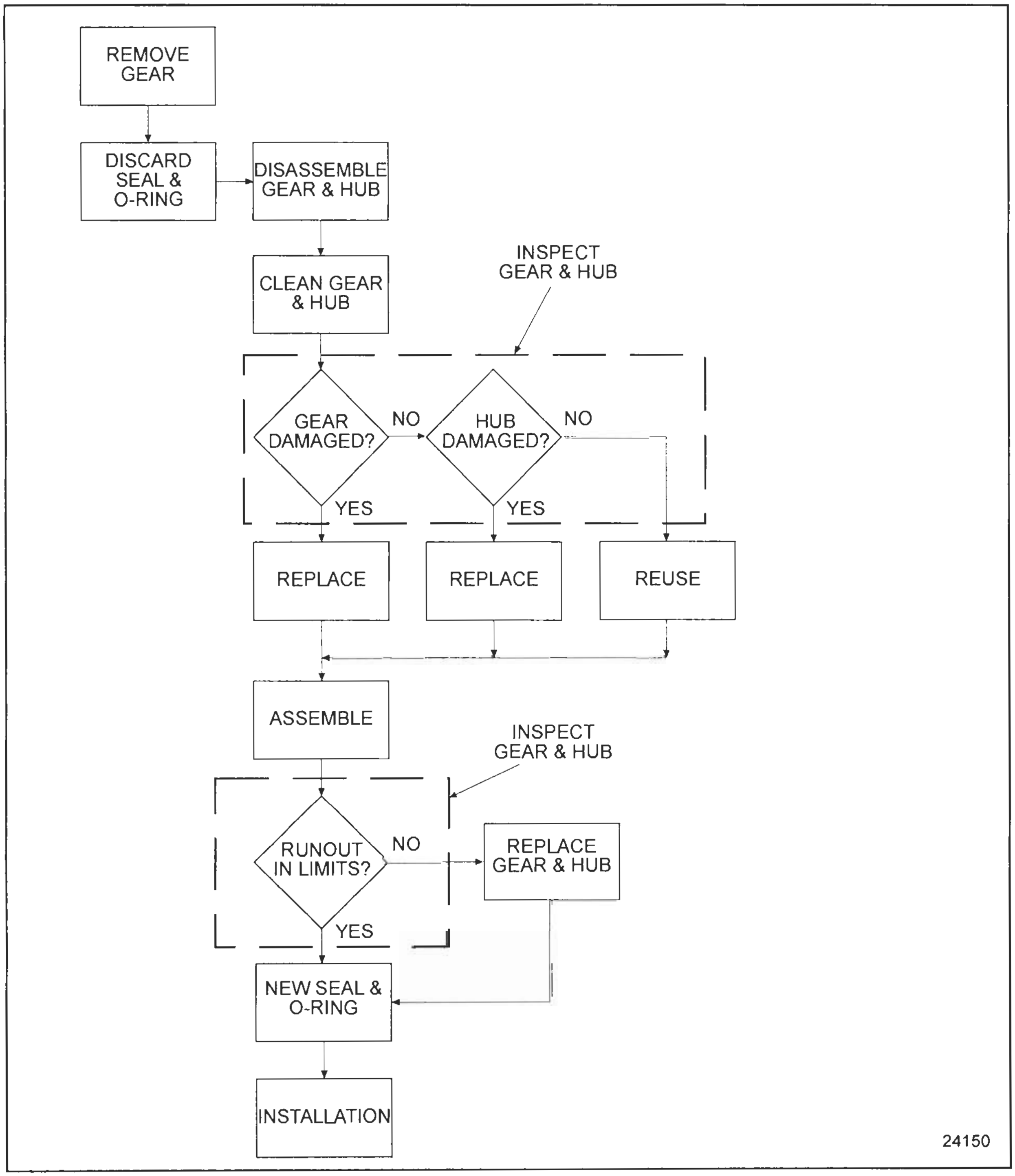


Figure 1–287 Flowchart for Repair or Replacement of Camshaft Drive Gear

1.23.2 Removal of Camshaft Drive Gear

Remove the camshaft drive gear as follows:

1. Remove the engine rocker cover. Refer to section 1.6.2.
2. Remove the camshaft drive gear access cover, fan bracket and camshaft retaining bolt. Refer to section 1.22.2.

NOTICE:
Use care when removing the camshaft thrust plate retaining bolts to prevent their accidental dropping into the gear case and causing engine damage.

3. Working through the access holes in the camshaft drive gear, remove the two bolts that retain the camshaft thrust plate to the cylinder head and No. 1 camshaft bearing cap. See Figure 1–288.

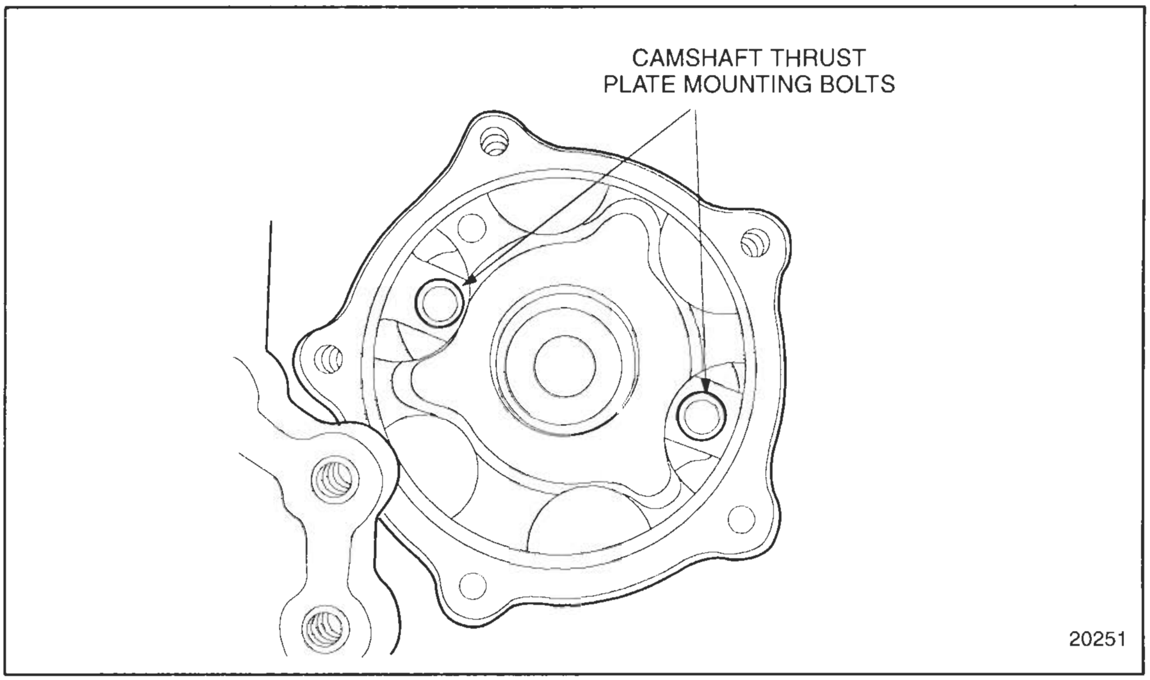


Figure 1–288 Camshaft Thrust Plate Retaining Bolts

4. Using the Camshaft Gear Pilot Tool, J 35906, pull the cam gear thrust plate assembly forward as far as possible to separate the assembly from the camshaft.
5. Remove the gear case cover. Refer to section 1.10.2.

6. Using a fiber mallet or plastic hammer, tap the rear face of the camshaft thrust plate forward until it is free of the gear case. See Figure 1-289.

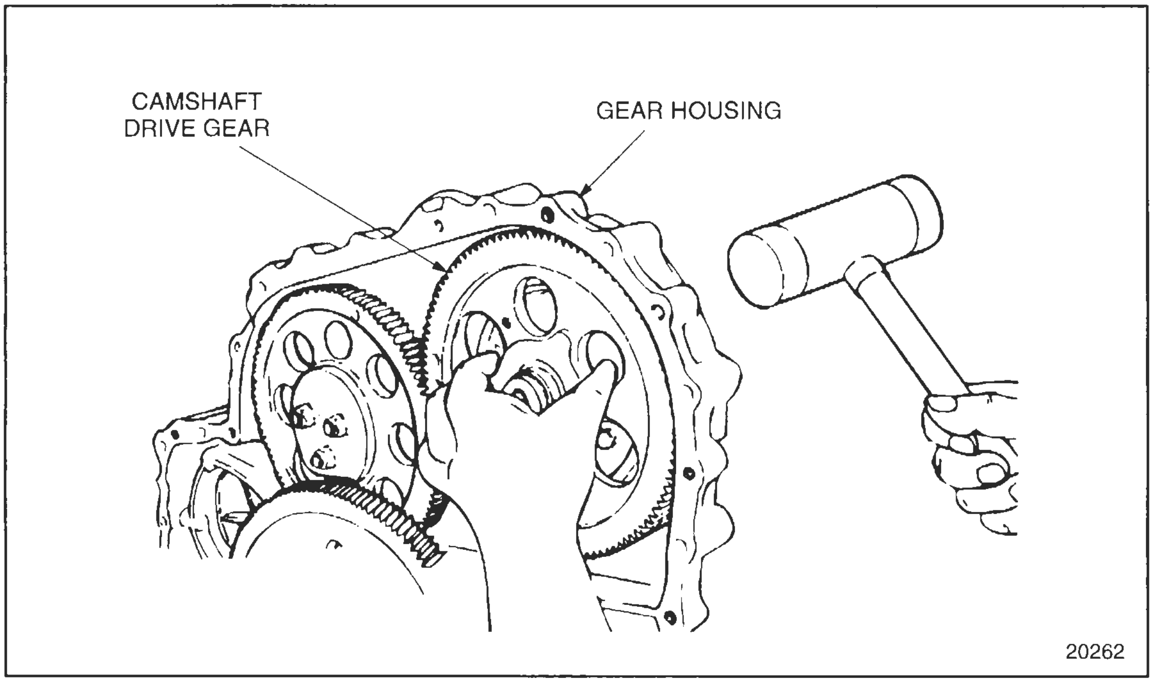


Figure 1–289 Removing Camshaft Thrust Plate Assembly

7. Remove the camshaft thrust plate, hub, and camshaft drive gear as an assembly. See Figure 1-290.

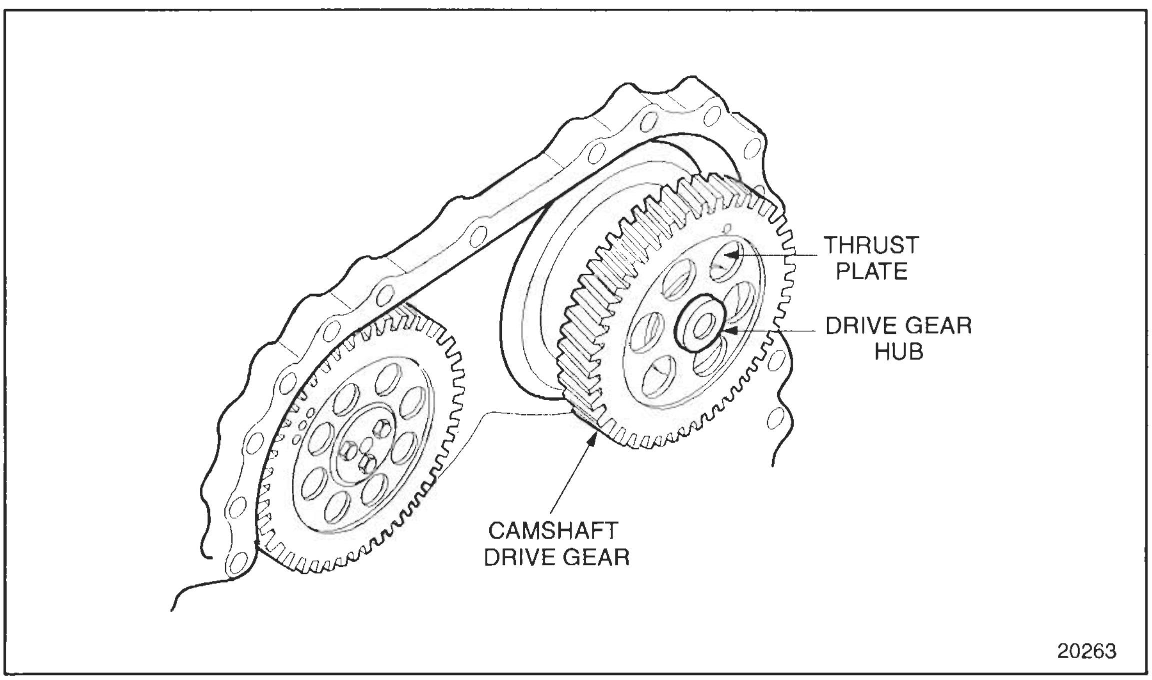


Figure 1–290 Camshaft Thrust Plate Assembly

8. Support the camshaft drive gear, with thrust plate facing down, on blocks.
9. Press the hub out of the camshaft drive gear until the hub separates from the camshaft thrust plate. See Figure 1–291.

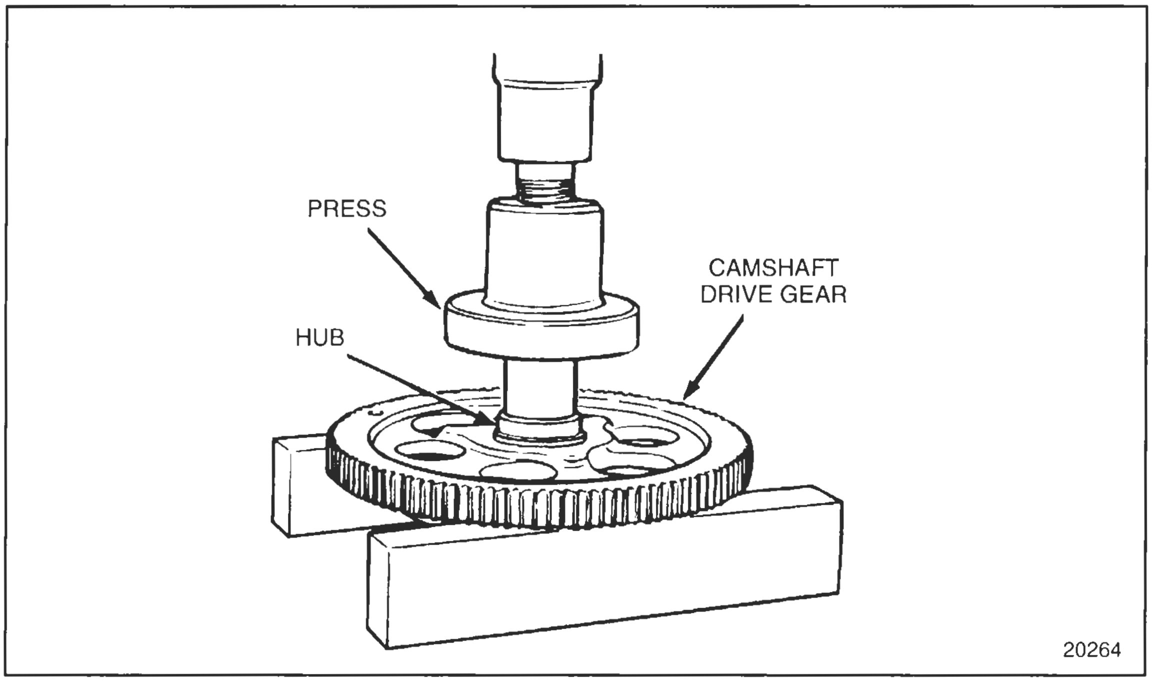


Figure 1–291 Camshaft Hub Removal

10. Remove the O-ring and seal from grooves int the camshaft thrust plate. Discard O-ring and seal.

1.23.2.1 Inspection of Camshaft Drive Gear

Inspect camshaft drive gear as follows:

1. Clean all parts with fuel oil.

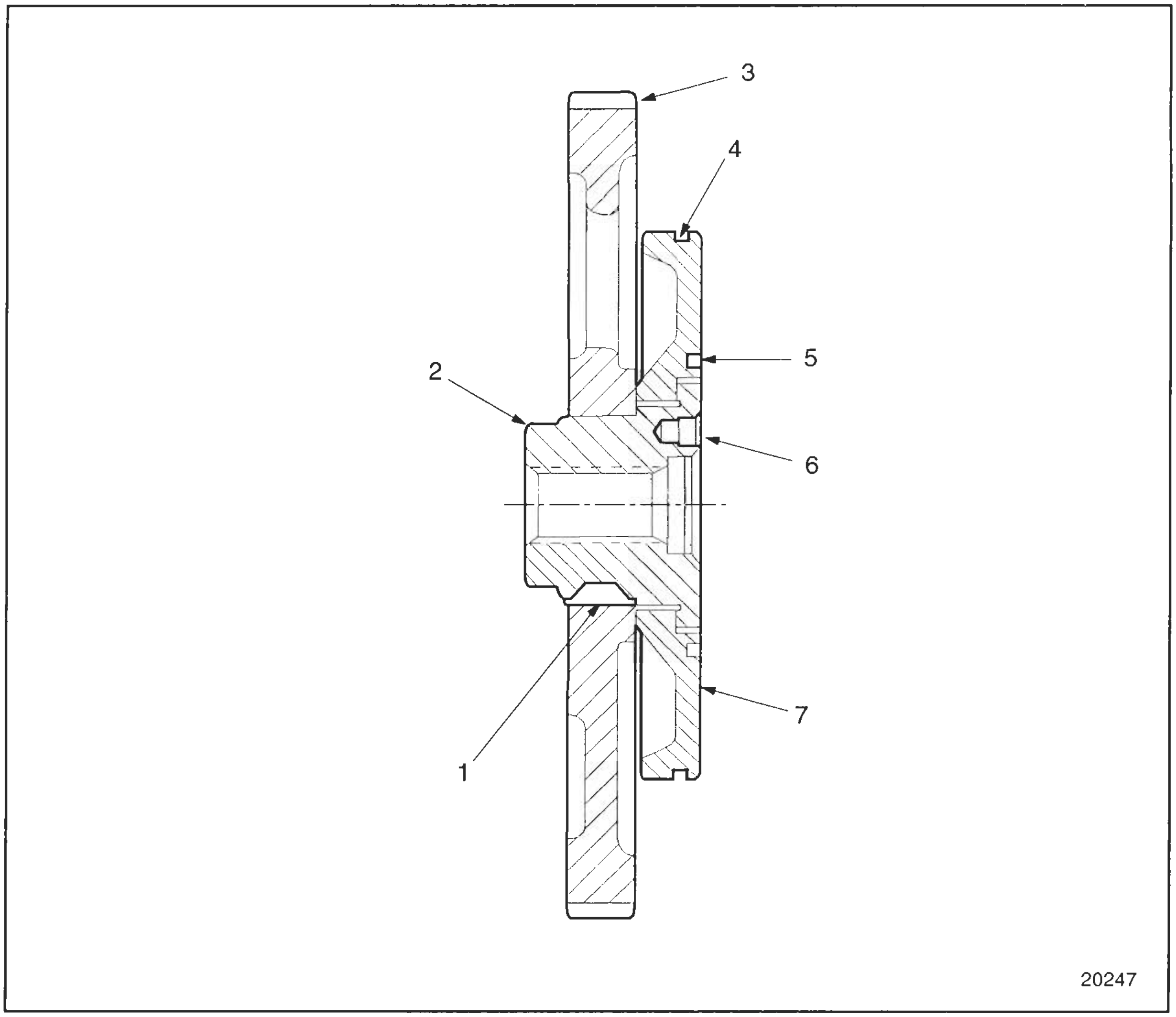
CAUTION:
To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

2. Dry them with compressed air.
3. Examine the camshaft drive gear teeth for scoring, pitting, excessive wear and cracking, peening of the Woodruff key slot.
4. If camshaft drive gear is damaged, replace drive gear.
5. Inspect the camshaft drive gear hub for scoring, pitting, galling or cracking, peening of the Woodruff key slot.
6. If damaged, replace drive gear hub.

1.23.3 Installation of Camshaft Drive Gear

Install the camshaft drive gear, hub and thrust plate as follows:

1. Coat the contact surfaces of the hub and camshaft thrust plate with clean engine oil. See Figure 1-292.



1. Woodruff Key
2. Hub, Camshaft Drive Gear
3. Drive Gear, Camshaft
4. Groove, O-ring
5. Groove, Seal
6. Dowel Hole, Camshaft
7. Thrust Plate, Camshaft

Figure 1-292 Cross-Section of Camshaft Drive and Related Parts

2. Install the hub to the camshaft thrust plate.
3. Install the key into the keyway on the hub.
4. Apply a thin film of Lubriplate to the bore of the camshaft gear.
5. Support the hub from the engine side.

NOTICE:
A minimum force of 20 kN (4500 lb) must be obtained when pressing the gear on the hub which can distort camshaft gear if applied off center. Only apply force to the inner hub of the gear when pressing.

6. Align the keyway in the camshaft drive gear with the key in the hub and press the gear, timing markup, onto the hub until it is firmly seated against the shoulder.

1.23.3.1 Test of Camshaft Drive Gear Assembly Runout

Measure the camshaft drive gear assembly runout as follows:

1. While supporting the camshaft thrust plate on blocks, position the camshaft drive gear assembly with the engine side facing down.
2. Assemble a dial indicator and magnetic base with the indicator stem rests on the face of the camshaft drive gear, just inboard of the drive gear teeth. Zero the dial indicator.
3. Rotate the drive gear two full rotations while **reading the total indicated runout**.

NOTE:
The total amount the dial indicator needle moves to the left and right of zero, added together, gives the total indicated runout Total Indicator Reading (TIR).

[a] Maximum allowable TIR is 0.114 mm (.0045 in.).
[b] If TIR exceeds limit, replace parts.

1.23.4 Installation of Camshaft Drive Gear

Continue installing camshaft drive gear assembly as follows:

1. Coat the camshaft thrust plate O-ring with clean engine oil.
2. Install it into its groove in the camshaft thrust plate.
3. Install diamond seal into its groove on the engine side of the thrust plate.
4. Be sure the O-ring sealing surface of the gear case is clean and free of burrs.
5. Install the hub and camshaft thrust plate to the opening in the gear case. The depression in the rear face of the camshaft thrust plate must be positioned at 12 o'clock, see Figure 1-286, to align the retaining bolts in the thrust plate with those in the head and No. 1 cam cap.
6. Using a fiber mallet or plastic hammer, tap the camshaft drive gear at 90° intervals toward the engine, until the thrust plate bolts can be started in the cylinder head and No. 1 camshaft cap.

NOTICE:
Make sure camshaft dowel hole in camshaft drive hub is aligned with camshaft dowel prior to tightening thrust plate bolts. A misaligned hub can cause damage to the camshaft and thrust plate components

NOTICE:
Use care when installing the camshaft thrust plate retain bolts to prevent accidentally dropping them into the gear case and causing damage to gear train.

7. Using a 13 mm socket and ratchet, tighten the thrust plate bolts alternately and evenly to draw the thrust plate straight into the gear case. Tighten the bolts to 30-38 N·m (22-28 lb·ft) torque.

8. Install gear case cover. Refer to section 1.10.3.

NOTICE:
Always hold the camshaft drive gear stationary using camshaft drive gear retaining tool, J 35652–A, to prevent component damage, while loosening or tightening the camshaft drive gear–to–camshaft bolt.

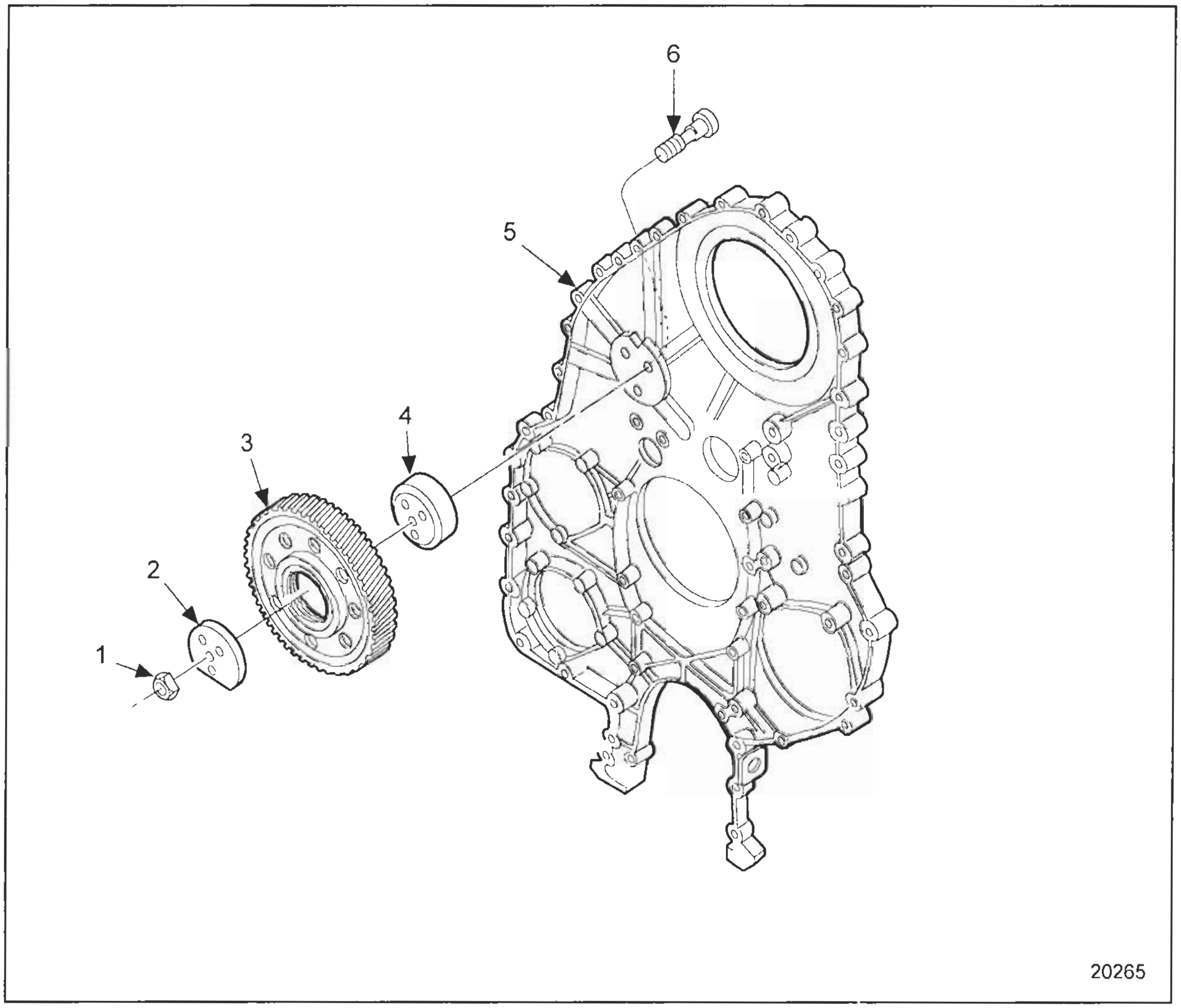
9. Once the gear case cover has been installed and secured, install the camshaft drive gear retaining tool, J 35652–A.

NOTE:
Before installing the fan support bracket and camshaft drive gear access cover, it will be necessary to install and tighten the camshaft drive gear retaining bolt, and to measure and adjust the adjustable gear–to–camshaft drive gear lash.

10. Install and torque the camshaft drive gear retaining bolt to 425 N·m (310 lb·ft).
11. Check the gear train timing and adjustable idler gear–to–camshaft drive gear lash. Refer to section 1.21.2.1.
12. Install the camshaft drive gear access cover and fan bracket. Refer to section 1.22.5.
13. Install any components that were removed for access to the gear case cover.
14. Check the lubricating oil. Refer to section 13.5.1.
15. Check the coolant level. Refer to section 13.5.4.

1.24 ADJUSTABLE IDLER GEAR ASSEMBLY

The adjustable idler gear is a straight–cut gear, mounted on a bushing pressed into the center of the gear, which in turn is supported on a stationary hub. The hub is secured to the gear case by a retaining plate, three studs, and locknuts. The studs are pressed into the gear case from the rear, and the flanged locknuts are installed after the gear, hub and hub retaining plate are installed. See Figure 1–293.



1. Locknut, Adjustable Idler Gear
2. Retaining Plate, Adjustable Idler Gear Hub
3. Gear Assembly, Adjustable Idler
4. Idler Hub, Adjustable
5. Gear Case
6. Stud, Adjustable Idler Gear (3)

Figure 1–293 Adjustable Idler Gear and Related Parts

The adjustable idler gear is pressure lubricated by engine oil fed to a gallery drilled into the gear case. This gallery indexes with the cylinder block oil gallery. See Figure 1-294.

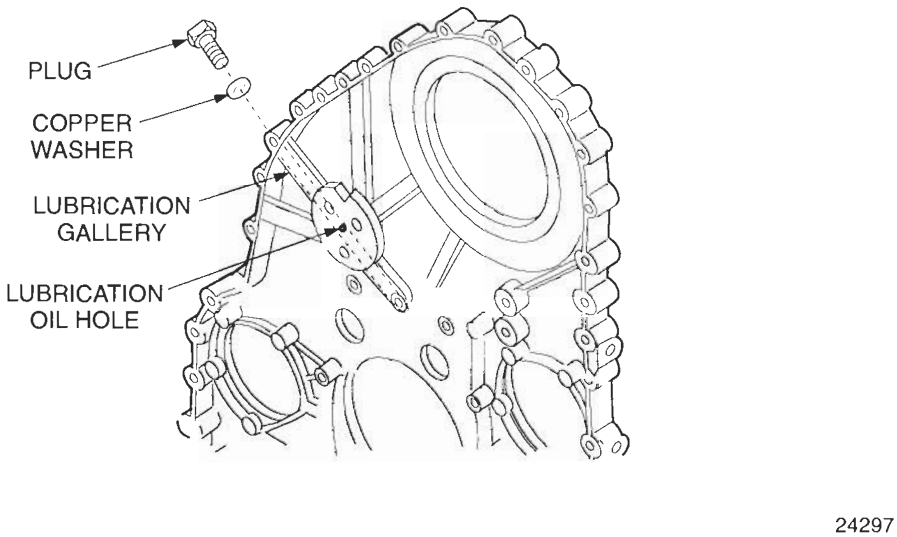


Figure 1–294 Adjustable Idler Gear Lubrication

The adjustable idler gear bushing has a series of machined grooves in the contact surface, for oil retention. The bushing is not serviced separately. If the bushing becomes worn or damaged, the gear and bushing must be replaced as an assembly.

There are three bolt holes in the hub where it is inserted over the studs. See Figure 1-295.

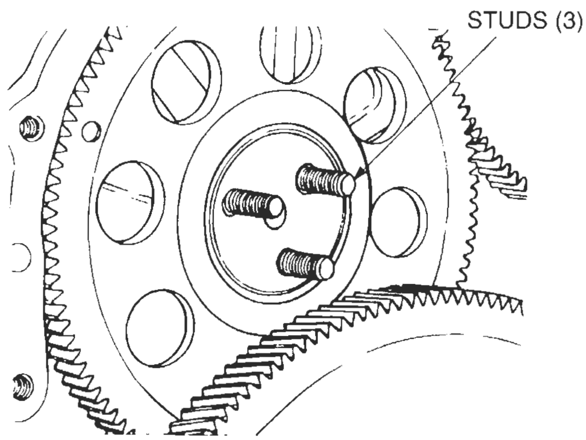


Figure 1–295 Adjustable Idler Gear and Hub Mounting

The top two holes are elongated, to allow the idler gear and hub assembly to be moved in relationship to the camshaft drive gear. The bottom stud hole is not elongated, and is a close fit to the stud. This allows the adjustable idler gear to pivot on the bottom stud, so the adjustable idler gear to camshaft drive gear lash can be adjusted without changing the clearance between the adjustable idler gear and camshaft idler gear. The adjustable idler gear retaining plate has a flat on the bottom to clear the bull gear for removal and installation. See Figure 1–296.

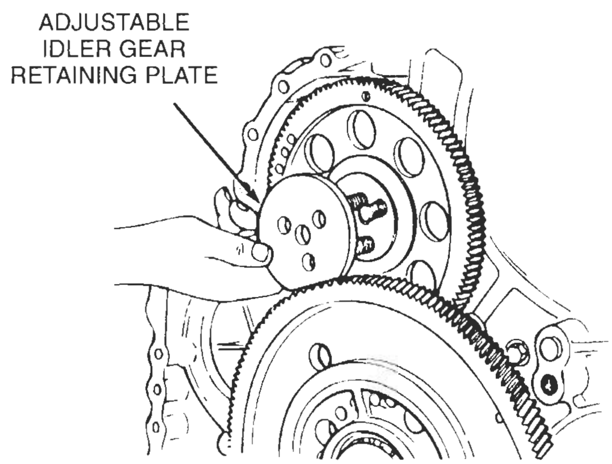


Figure 1–296 Adjustable Idler Gear Retaining Plate

1.24.1 Repair or Replacement of Adjustable Idler Gear Assembly

To determine if repair or replacement of the adjustable idler gear assembly is necessary, perform the following procedure. See Figure 1–297.

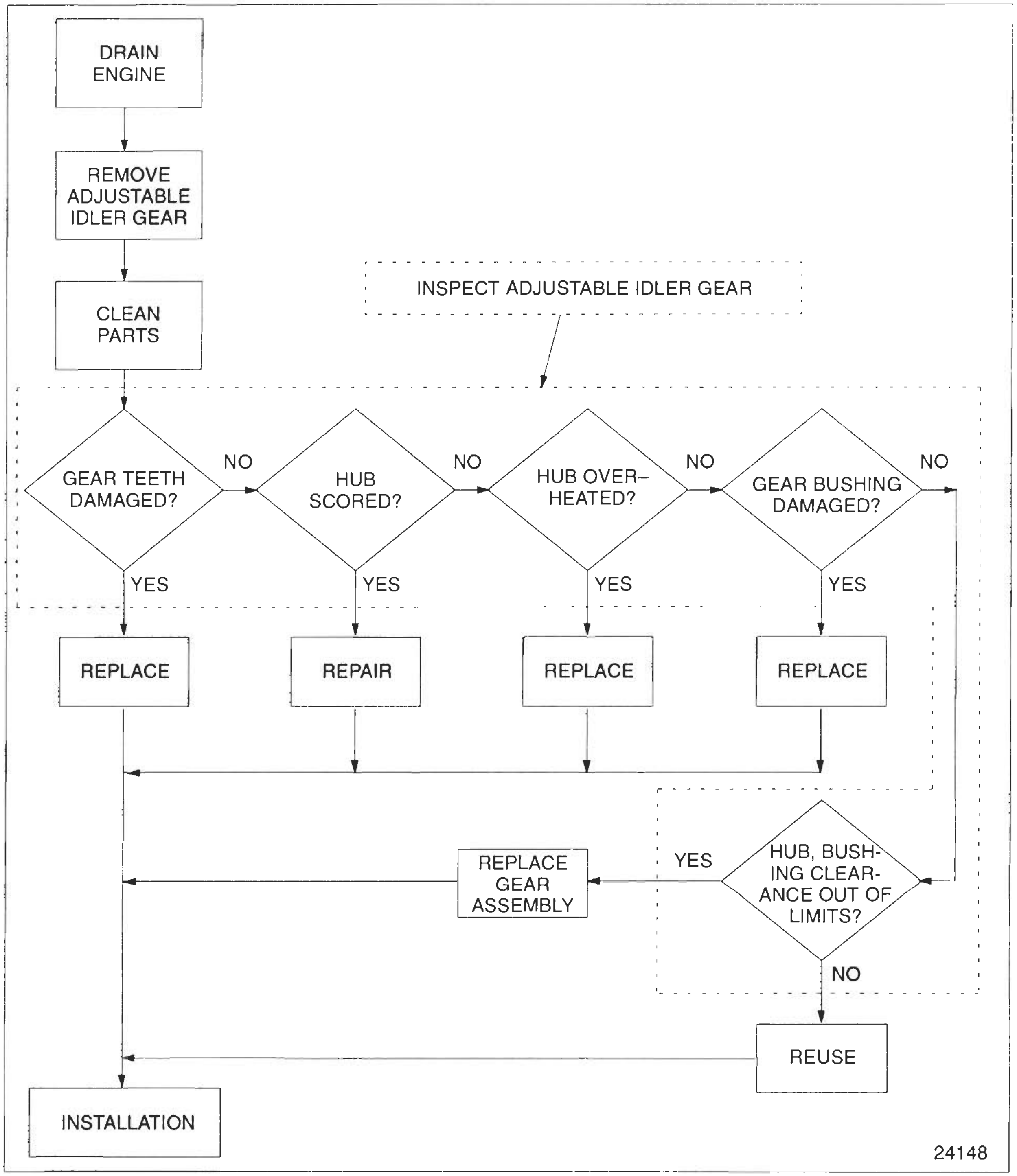
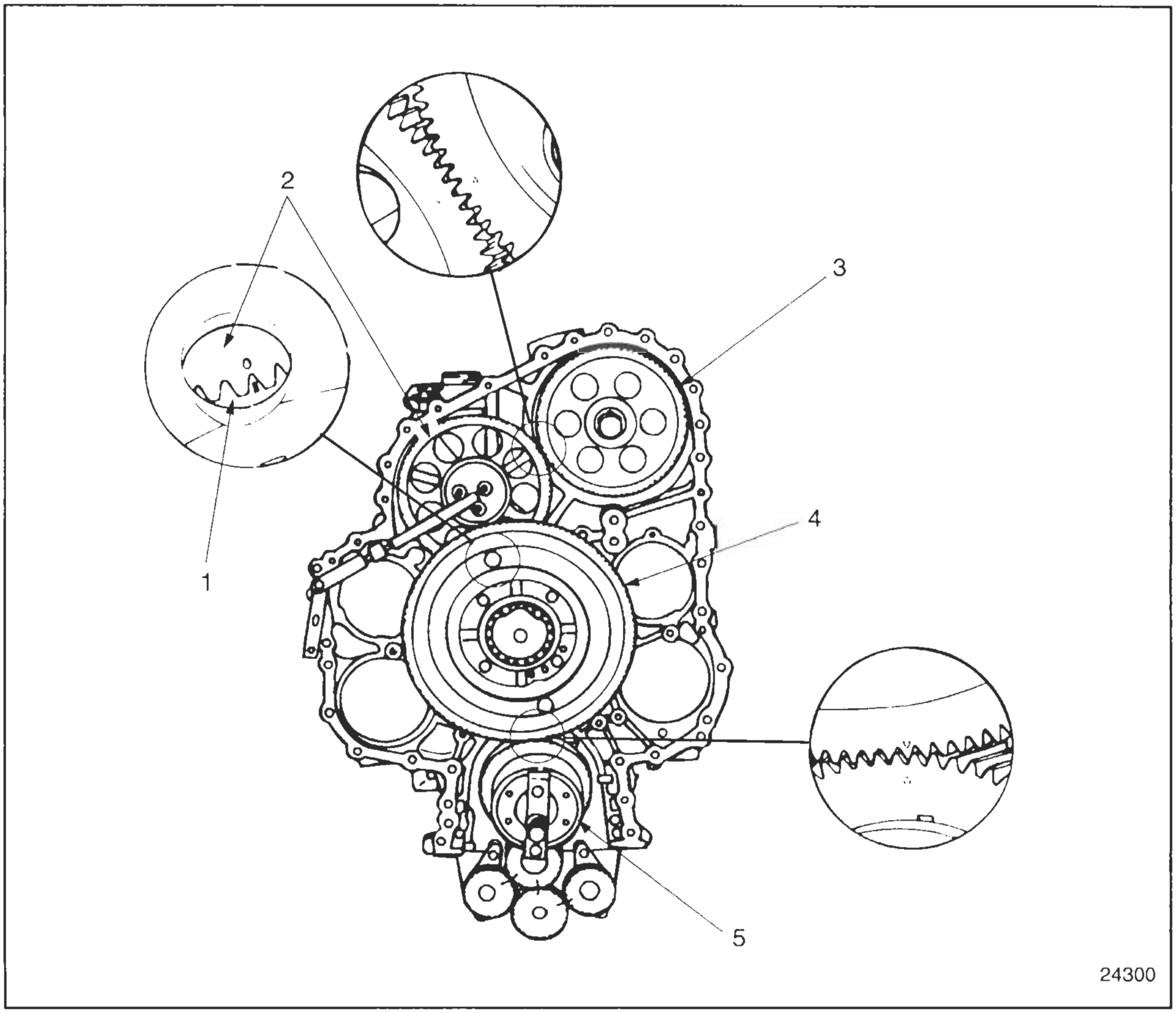


Figure 1–297 Flowchart for Repair or Replacement of Adjustable Idler Gear Assembly

1.24.2 Removal of Adjustable Idler Gear Assembly

Align gear train timing marks. Refer to section 1.21.2.1 before the removal of any gears. See Figure 1–298.

NOTE:
In order to maintain the proper timing between the crankshaft and the camshaft, a series of timing marks are stamped or etched on the gears in the gear train. With the timing marks aligned, the gears can be replaced exactly as removed.



1. Idler Gear, Camshaft
2. Idler Gear, Adjustable
3. Drive Gear, Camshaft
4. Bull Gear
5. Timing Gear, Crankshaft

Figure 1–298 Engine Gear Train and Timing Marks

Drain the engine assembly as follows:

1. Drain the cooling system. Refer to section 13.5.4.
2. Drain the engine lubricating oil. Refer to section 13.5.1.

Remove the adjustable gear assembly as follows:

1. Remove the oil pan. Refer to section 3.9.2.
2. Remove the gear case cover. Refer to section 1.10.2.
3. Secure the engine barring tool, J 36237, to the front of the crankshaft. See Figure 1–299.

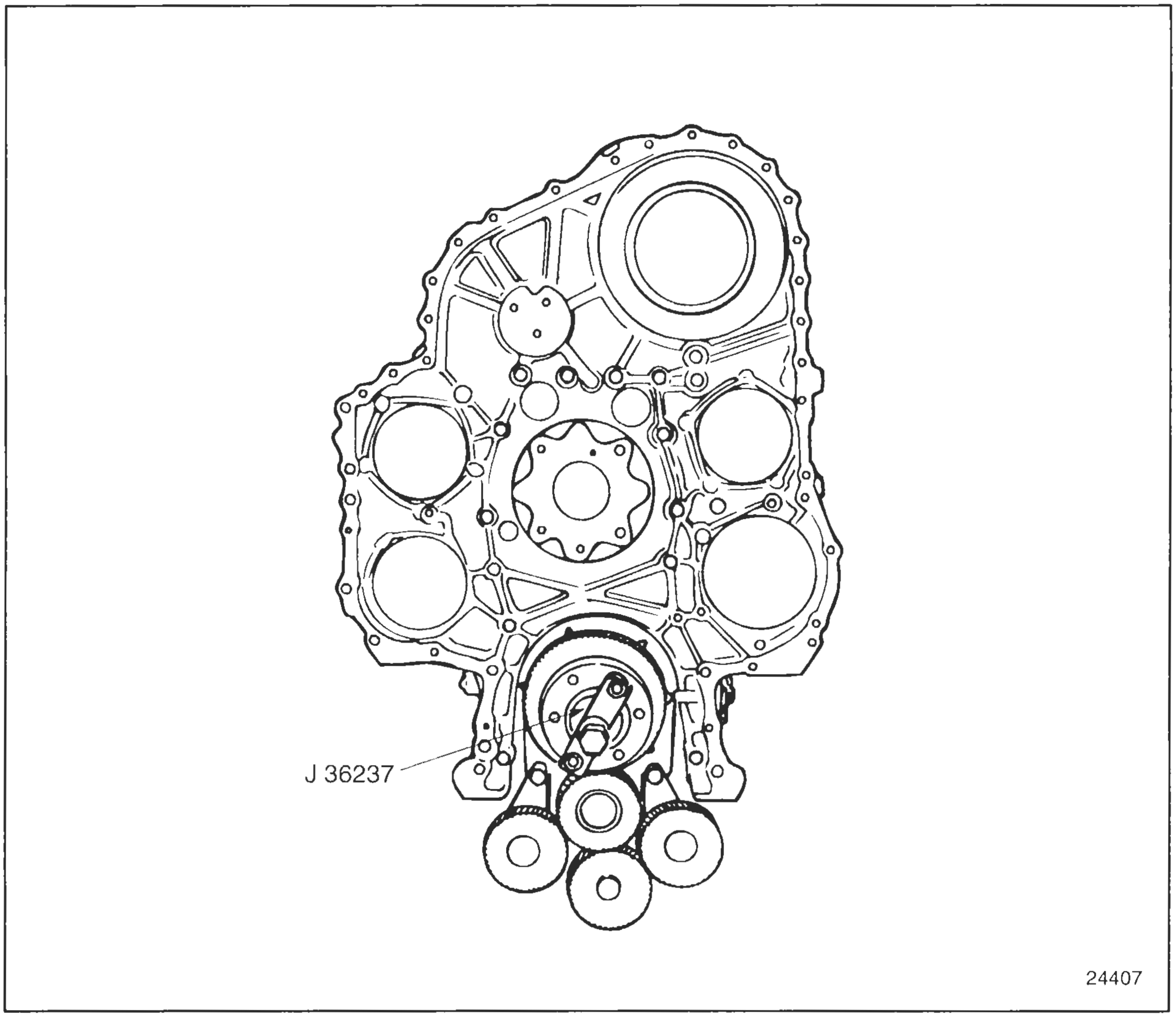


Figure 1–299 Barring Engine Over

4. Install the crankshaft protector, J 35994, to the oil seal contact area of the crankshaft.

NOTICE:
Always use Crankshaft Protector, J 35994, to guard against damage to the oil seal area of the crankshaft. When removing the bull gear or camshaft idler gear and hub assembly, do not to come in contact with the oil seal contact surface of the crankshaft. If sealing surface is scratched, an oil leak may result.

5. Working through the four access holes in the bull gear and camshaft idler assembly, remove two of the four bolts that secure the bull gear and camshaft idler gear hub to the cylinder block. See Figure 1–300.

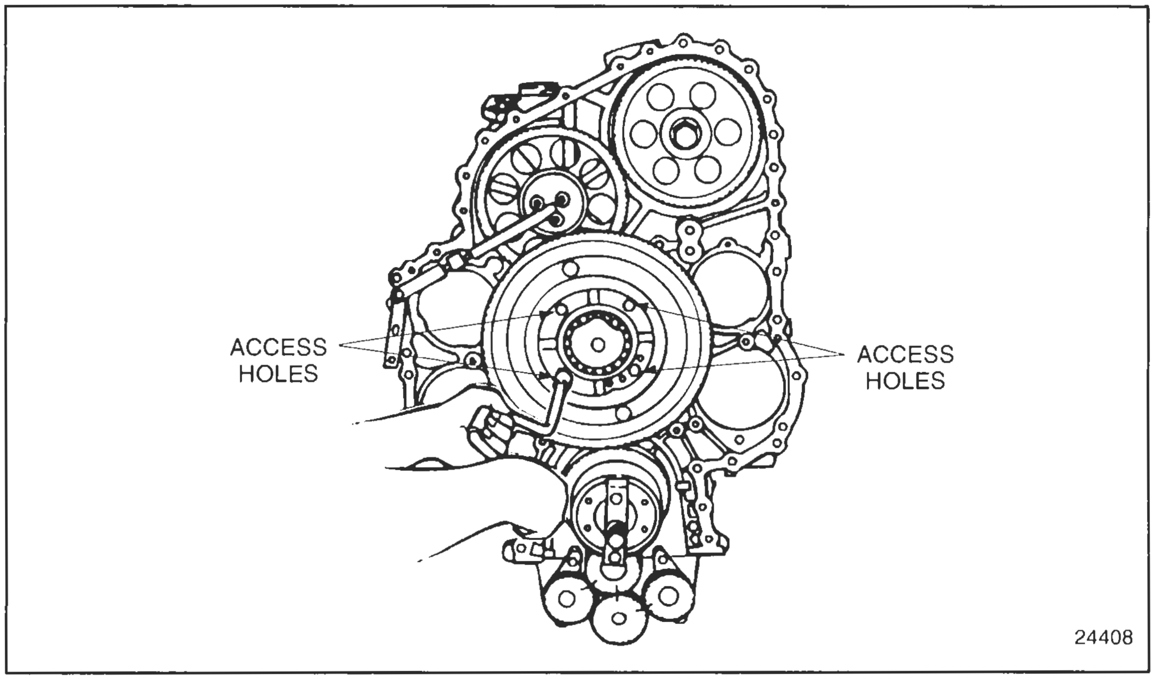


Figure 1–300 Removing Bull Gear and Camshaft Idler Gear and Hub

6. Install two bull gear guide studs, J 35785, to the holes from where the bolts were removed.
7. Remove the remaining two bull gear and camshaft idler gear hub bolts.
8. Grasp the bull gear and remove the bull gear and camshaft idler gear and hub assembly from its recess in the cylinder block.
9. Remove the three adjustable idler gear flanged locknuts.
10. Remove the adjustable idler gear hub retaining plate.
11. Remove the adjustable idler gear and hub.

1.24.2.1 Inspection of Adjustable Idler Gear Assembly

Inspect the adjustable idler gear assembly as follows:

1. Wash the adjustable idler gear, hub, and retaining plate thoroughly in clean fuel oil.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

2. Dry with compressed air.
3. Examine the gear teeth for evidence of scoring, pitting and wear.
4. If severely damaged or worn, replace the gear.

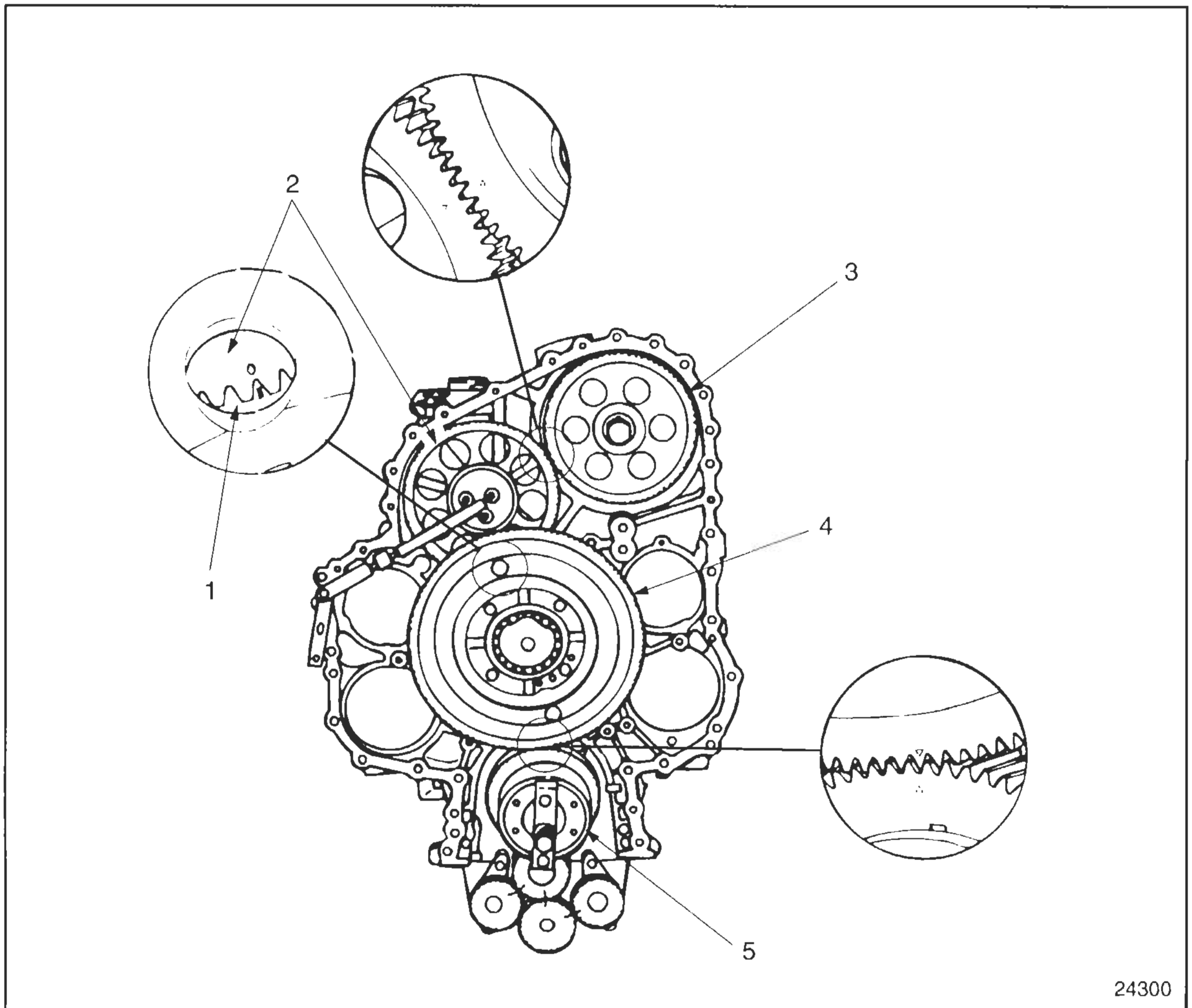
NOTE:
If gear teeth are damaged, also inspect the other gears in the gear train.

5. Inspect the contact surface of the hub for scoring or evidence of overheating (blue discoloration).
6. If hub has become overheated, replace the hub.
7. If slight irregularities are present, remove with a fine stone or emery cloth.
8. Check the lubrication hole and gallery in the gear case for blockage.
9. If blocked, clear the lubrication hole.
10. Inspect the bushing contact surface of gear and bushing assembly for signs of scoring, discoloration due to overheating, or excessive wear.
11. If the surface of the bushing is not acceptable, replace the gear and bushing as an assembly.
12. Measure the clearance between the bushing and hub.
13. If the clearance is more than 0.035–0.078 mm (.0013–.0030 in.), replace the gear and bushing as an assembly.

1.24.3 Installation of Adjustable Idler Gear Assembly

Install the adjustable idler gear and related parts as follows:

1. Coat the contact surfaces of the hub and idler gear bushing with clean engine oil.
2. Install the hub, with the word "OUT" facing outward, to the three studs in the gear case with the oil supply hole in the hub towards the gear case.
3. Align the timing marks on the face of the adjustable idler gear and camshaft drive gear and install the adjustable idler gear to its hub. See Figure 1–301.



1. Idler Gear, Camshaft
2. Idler Gear, Adjustable
3. Drive Gear, Camshaft
4. Bull Gear
5. Timing Gear, Crankshaft

Figure 1–301 Engine Gear Train and Timing Marks

4. Install thrust plate with the relief at the bottom.
5. Install the three flanged locknuts, finger tight.
6. Install the bull gear guide studs, J 35785.
7. Install crankshaft protector, J 35994.
8. Coat the bearings and contact surfaces of the bull gear assembly with clean engine oil.
9. Looking through the inspection hole in the bull gear, align the timing marks on the camshaft idler gear (mounted to the rear of the bull gear) with the adjustable idler gear. Align the timing marks on the bull gear and crankshaft timing gear. Refer to section 1.21. Install the bull gear hub assembly to the cylinder block. Refer to section 1.25.3.
10. Install the gear case cover. Refer to section 1.10.3.
11. Using the gear lash adjusting tool, J 35596, adjust the gear lash between the adjustable idler gear and camshaft drive gear. Refer to section 1.24.3.
12. Install any other components that were removed for access to the gear case cover.

1.25 BULL GEAR AND CAMSHAFT IDLER GEAR ASSEMBLY

The bull gear and camshaft idler gear assembly is centrally located beneath the gear case cover. The larger bull gear is directly driven by the crankshaft timing gear. The bull gear directly drives all of the gear–driven engine accessories (except the oil pump and balance assembly), meshing with drive gears for the fuel pump drive, air compressor drive, power steering pump (if so equipped), water pump and accessory and alternator drive. See Figure 1–302.

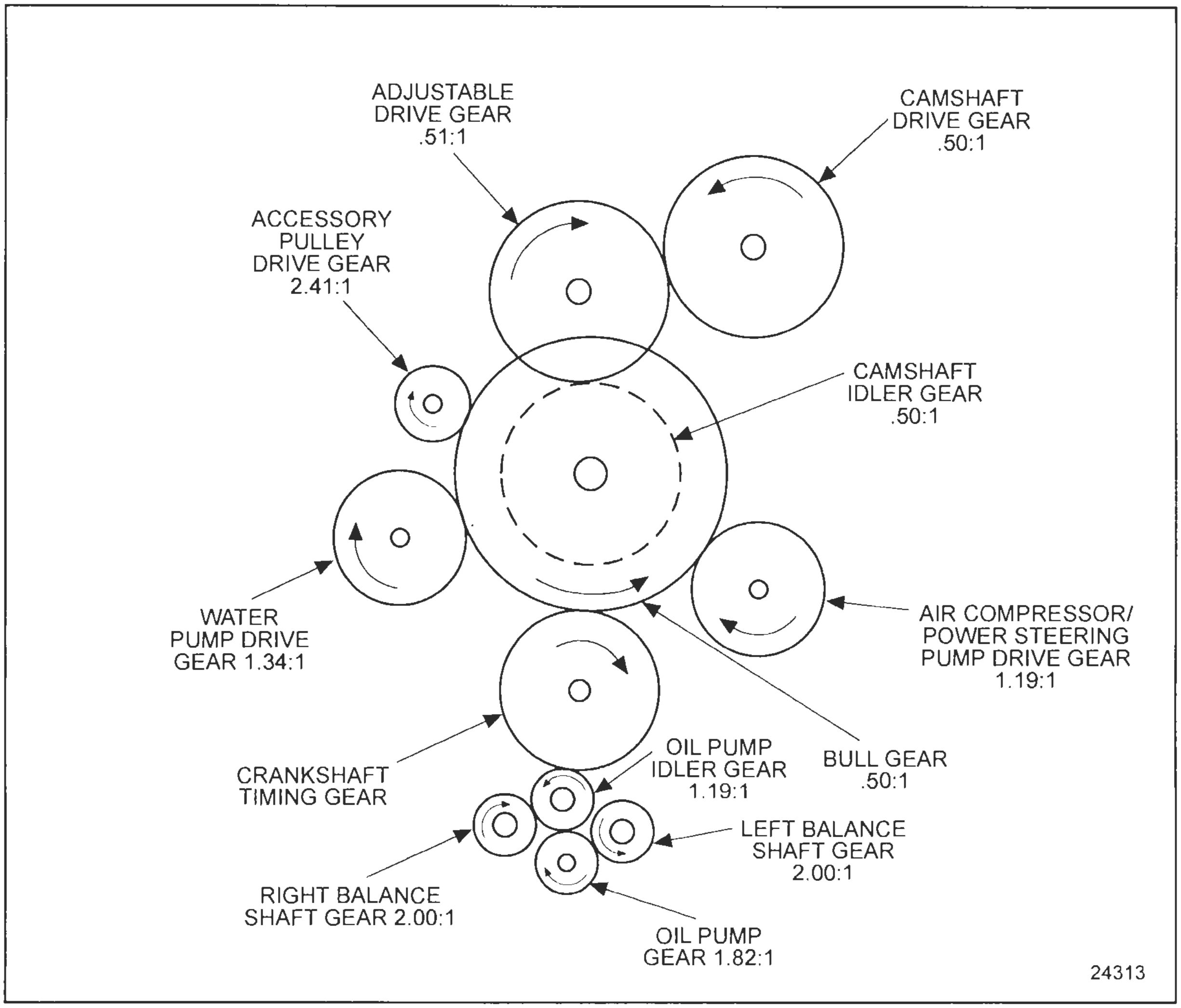
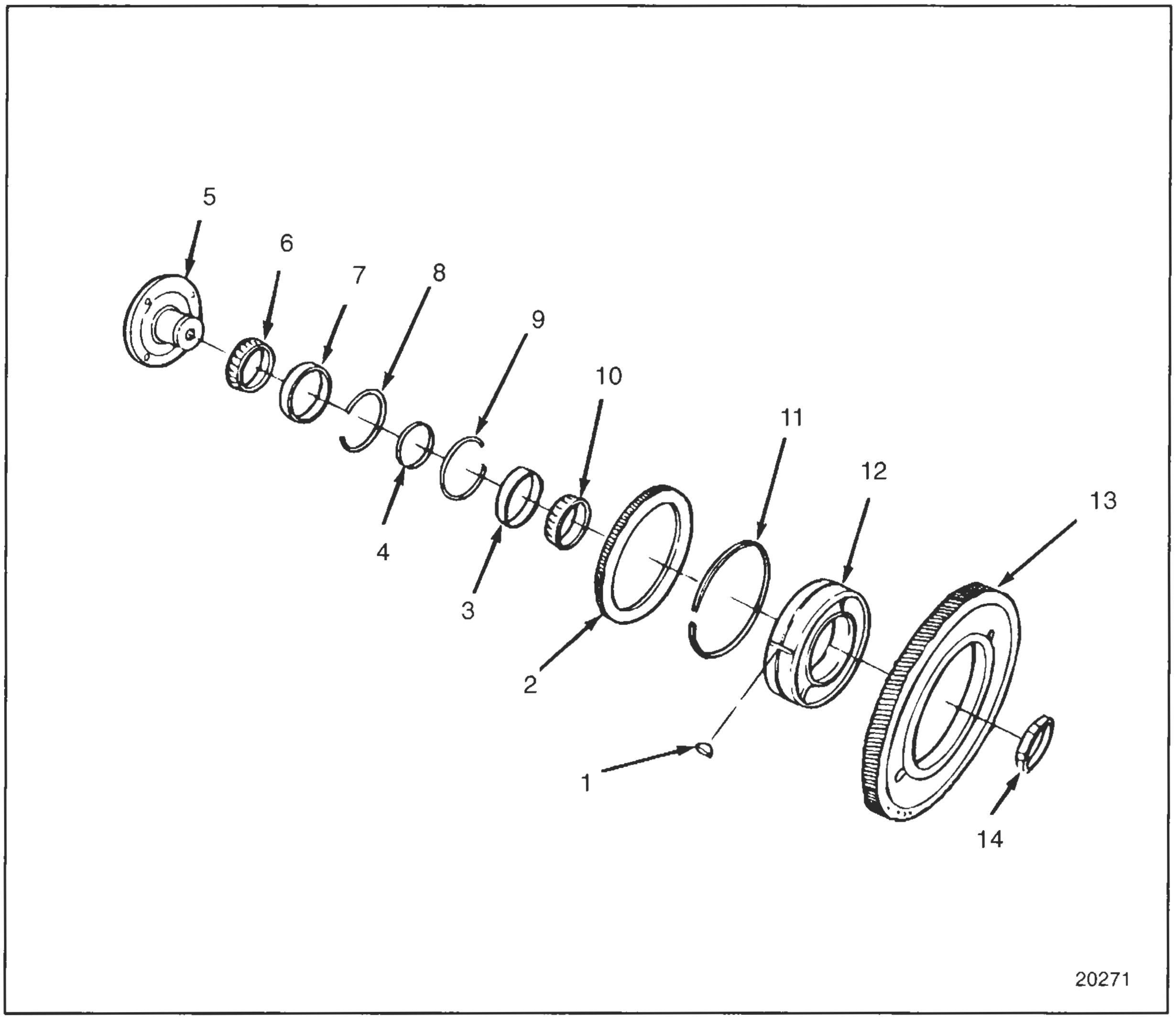


Figure 1–302 Engine Gear Train

The smaller camshaft idler gear is located behind the bull gear on the same carrier, and turns at the same speed as the bull gear. The camshaft idler gear drives an adjustable idler gear, mounted on a separate hub in the gear case. The adjustable idler gear drives the camshaft drive gear. The gear ratio of each gear in relationship to the crankshaft timing gear is shown directly below the gear title.

The bull gear and camshaft idler gear are a press-fit to the bull gear and camshaft idler gear carrier. See Figure 1-303.



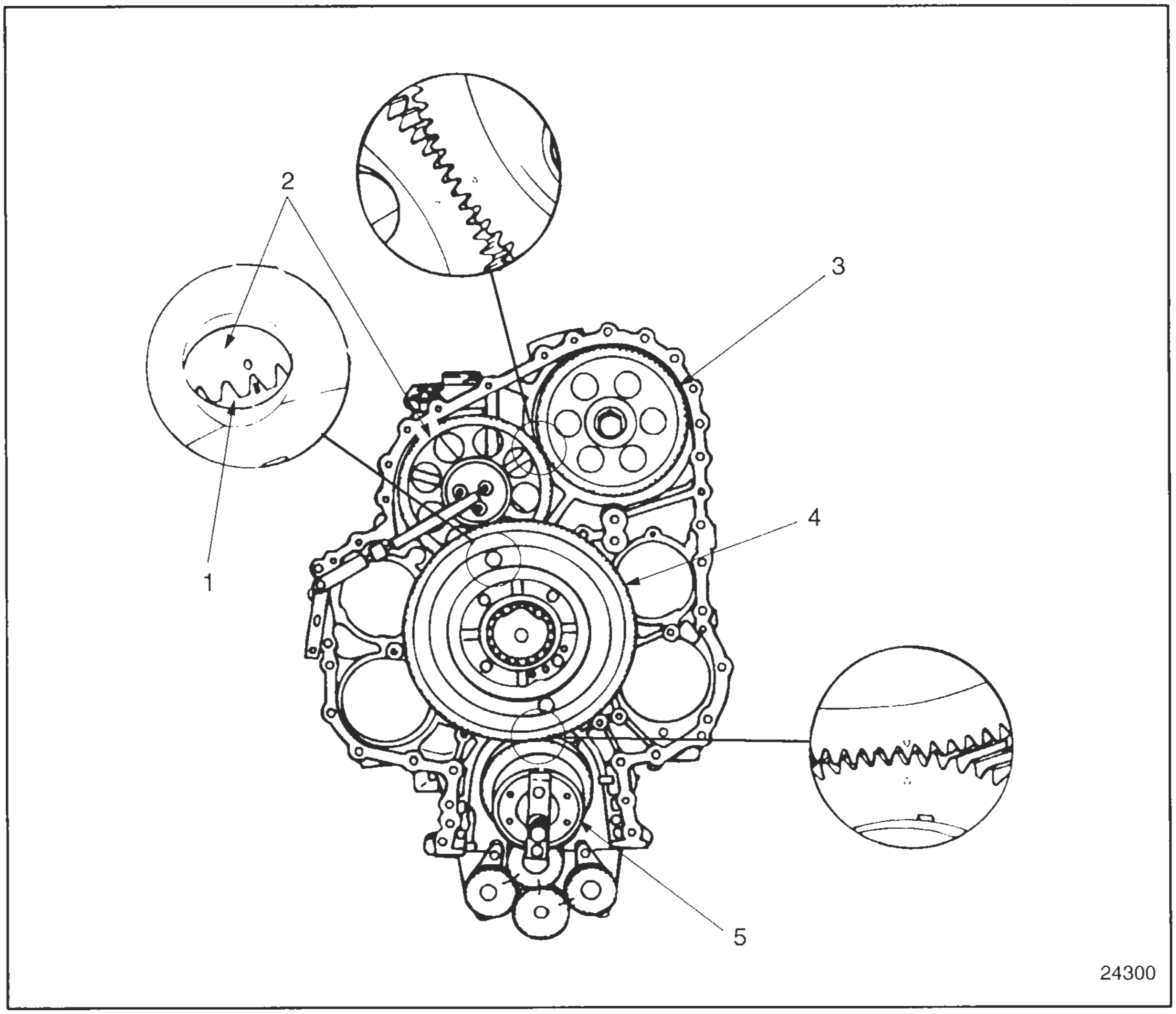
1. Woodruff Key
2. Camshaft Idler Gear
3. Bearing Race, Outer
4. Spacer Ring, Small
5. Hub
6. Bearing, Inner
7. Bearing Race, Inner
8. Snap Ring, Inner
9. Snap Ring, Outer
10. Bearing, Outer
11. Spacer Ring, Large
12. Carrier
13. Bull Gear
14. Thread Nut, Left Hand

Figure 1–303 Bull Gear and Related Parts

Both gears are keyed to the carrier by the same key. For earlier units, a spacer ring fits in a groove in the carrier between the bull gear and the camshaft idler gear. In later engines, this spacer was incorporated in the carrier. The carrier is supported by two tapered roller bearing assemblies that ride on a hub bolted to the engine block by four bolts. A selective-size spacer between the two bearing assemblies is used to obtain the correct bearing preload.

NOTE:
The bull gear and camshaft idler gear assembly is retained to the hub by a left–hand threaded nut.

The camshaft must be in time with the crankshaft timing gear. Since there are three gears between them, timing marks have been stamped or etched on the face of the gears to facilitate correct gear train timing. Refer to section 1.21.2.1 for gear train timing procedures. See Figure 1–304.



1. Idler Gear, Camshaft
2. Idler Gear, Adjustable
3. Drive Gear, Camshaft
4. Bull Gear
5. Timing Gear, Crankshaft

Figure 1–304 Engine Gear Train and Timing Marks

The backlash between the various mating gears in the gear train should be 0.051–0.229 mm (.002–.009 in.), and should not exceed 0.305 mm (.012 in.) backlash between worn gears. Refer to section 1.21.2.1.

NOTE:
All gear lash measurements should be taken with engine in an upright position.

The bull gear and camshaft idler gear assembly is pressure-fed lubricating oil through two holes in the bull gear recess area of the engine block. See Figure 1–305.

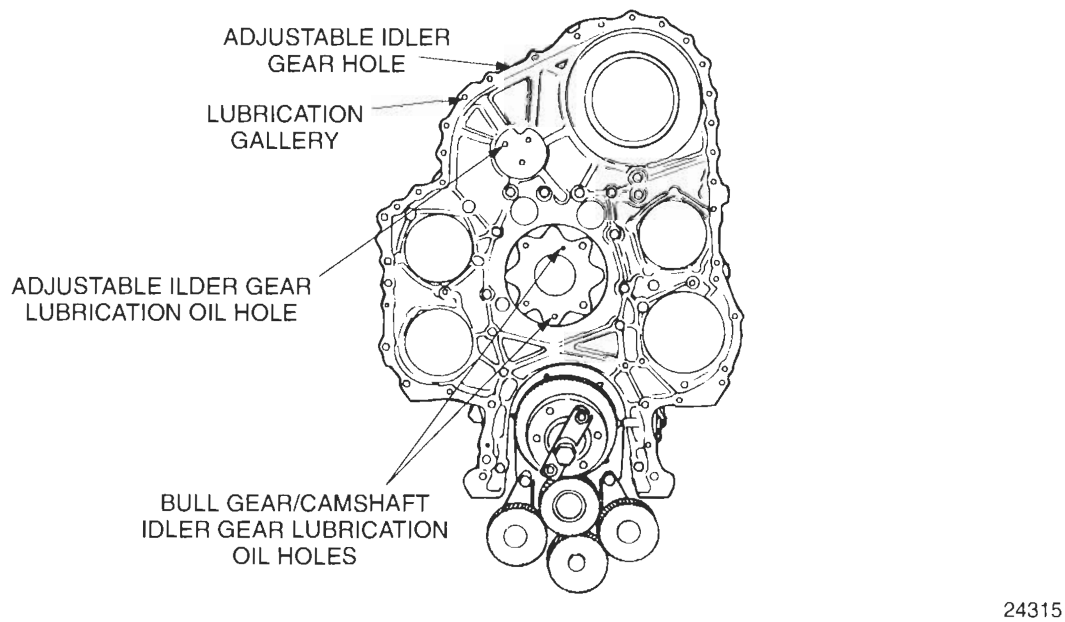


Figure 1–305 Bull Gear and Camshaft Idler Gear Lubricating Oil Hole Locations

These two holes are drilled into a main oil gallery. An internal oil passage, cast into the bull gear and camshaft idler gear hub relief at the rear of the hub indexes with these two oil holes to supply oil through a drilled passage to the two roller bearing assemblies.

1.25.1 Repair or Replacement of Bull Gear and Camshaft Idler Gear Assembly

To determine if repair or replacement of the bull gear and camshaft idler gear assembly is necessary, perform the following procedure. See Figure 1–306.

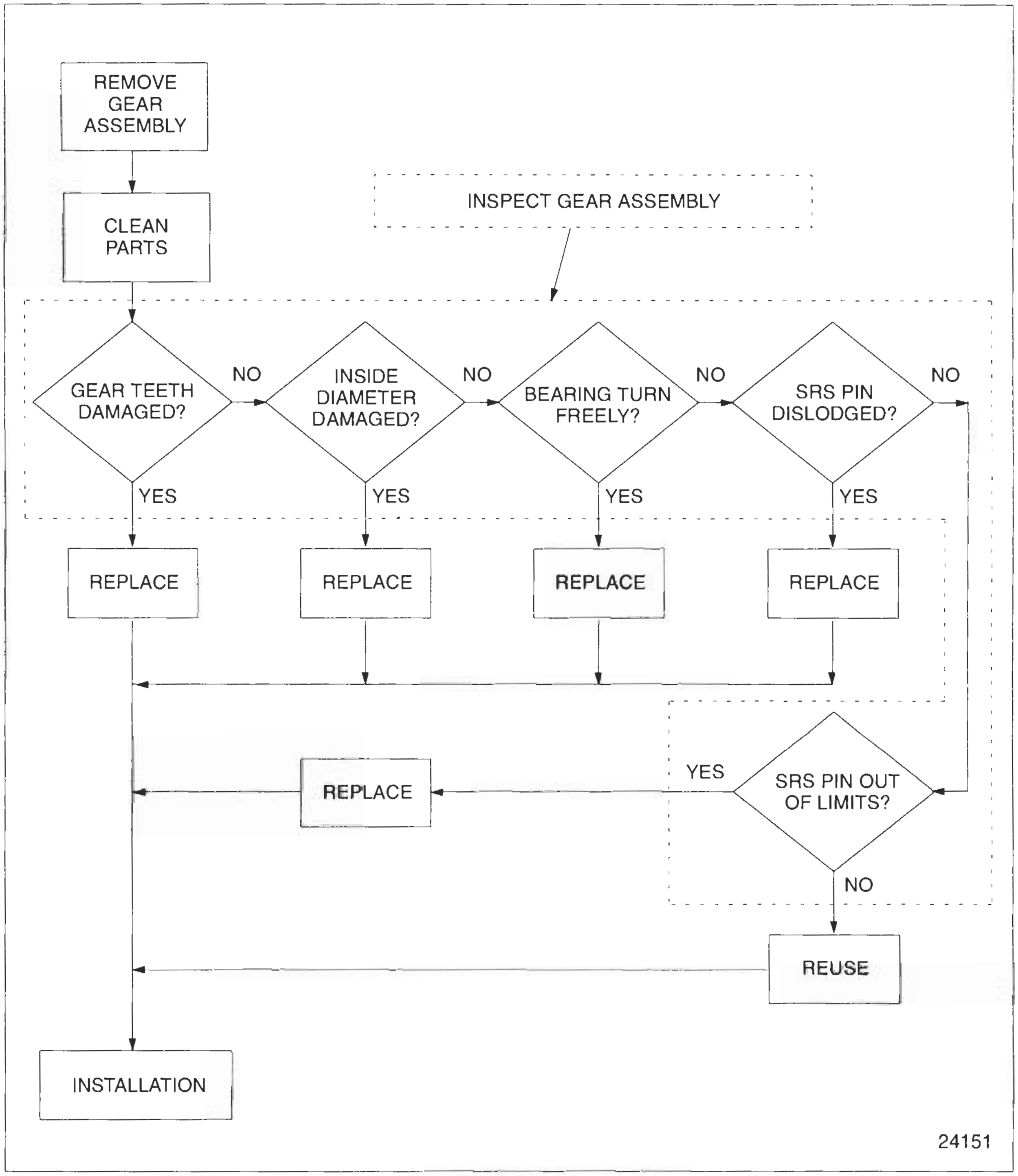


Figure 1–306 Flowchart for Repair or Replacement of Bull Gear and Camshaft Idler Gear Assembly

1.25.2 Removal of Bull Gear and Camshaft Idler Gear Assembly

Remove the bull gear and camshaft idler gear assembly as follows:

1. Remove the engine gear case cover. Refer to section 1.10.2.
2. Install the crankshaft protector, J 35994, to the oil seal contact area of the crankshaft.

NOTICE:
Use care when removing the bull gear and camshaft idler gear assembly from the engine so that it does not come in contact with the oil seal contact surface of the crankshaft. If this sealing surface is scratched, an oil leak may result.

3. Working through the four access holes in the bull gear carrier, loosen and remove two of the four bolts that secure the bull gear assembly to the cylinder block. See Figure 1–307.

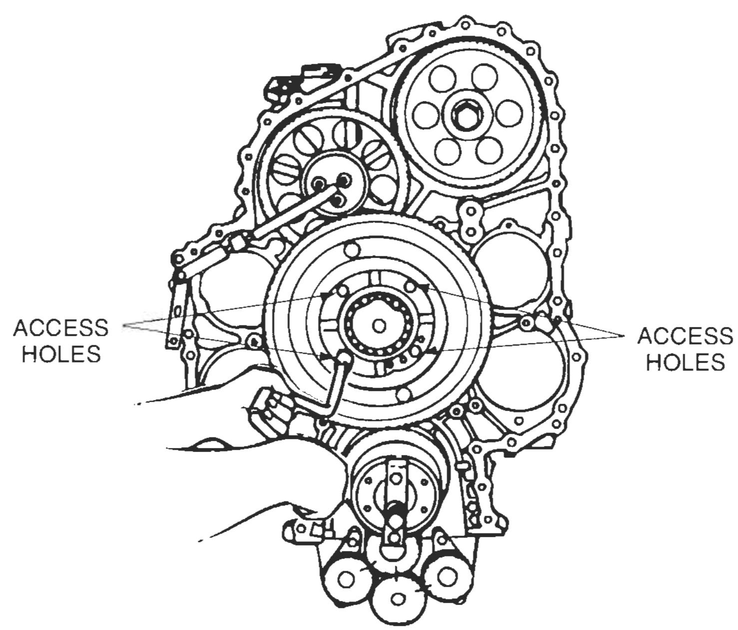


Figure 1–307 Removing Bull Gear Assembly Retaining Bolts

4. Install two bull gear guide studs, J 35785, into the holes the bolts from where they were removed.
5. Remove the two remaining bull gear retaining bolts.
6. Grasp the bull gear and pull the assembly straight out of the recess in the cylinder block.

1.25.2.1 Inspection of Bull Gear and Camshaft Idler Gear Assembly

Inspect the bull gear and camshaft idler gear assembly as follows:

1. Clean the bull gear and idler gear assembly in clean fuel oil.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

2. Dry the bull gear and idler gear assembly with compressed air.
3. Examine the gear teeth on both the bull gear and idler gear for evidence of scoring, cracking, pitting, and wear.
4. If either gear is damaged, replace the bull gear and idler gear assembly.
5. Inspect the inner diameter of both gears, where they are pressed on the carrier for evidence of gear movement
6. If there is any evidence of gear movement, replace the bull gear and idler gear assembly.
7. Place the bull gear and idler gear assembly on a bench, resting on the hub. Inspect the bearings for signs of distress or overheating.
8. If there is any bearing distress, replace the bull gear and idler gear assembly.
9. Coat the bearings with clean engine oil.
10. Slowly rotate the gears on the hub looking for binding of the bearing.
11. If the gears do not rotate freely on the hub, replace the bull gear and idler gear assembly.

NOTICE:

Care should be taken not to damage or dislocate the pin. The pin is installed at a set dimension which is used by the Synchronous Reference Sensor (SRS). Damage to pin will cause loss of engine performance.

Inspect the SRS pin in the bull gear as follows. See Figure 1-308.

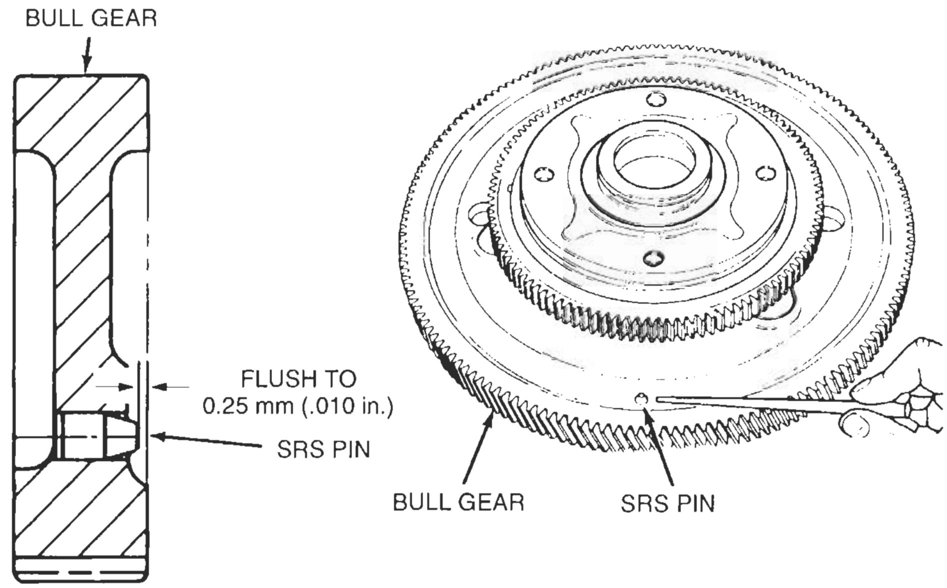


Figure 1-308 SRS Pin Location

1. Check the SRS pin for damage or looseness.
2. If the SRS pin is damaged or dislodged, replace the pin as follows:
   [a] Press the SRS pin from the bull gear. Discard pin.

NOTICE:
Do NOT reuse or readjust a pin once it has been installed. Damage to pin will cause loss of engine performance.

   [b] Apply Loctite 609 (PT 7260) to pin.
   [c] Press pin flush to 0.25 mm (.010 in.) below bull gear surface.
3. Using straight edge and thickness gages, measure recess of SRS pin.
4. If pin is not flush to 0.25 mm (.010 in.) below bull gear surface, repeat step 2.

1.25.3 Installation of Bull Gear and Camshaft Idler Gear Assembly

Install bull gear assembly and camshaft assembly as follows:

1. Inspect the bull gear and camshaft idler gear access opening in the gear case and remove any foreign material. Be sure the lubrication oil holes are clear and free.
2. Install two bull gear guide studs, J 35785, to the cylinder block. See Figure 1–309.

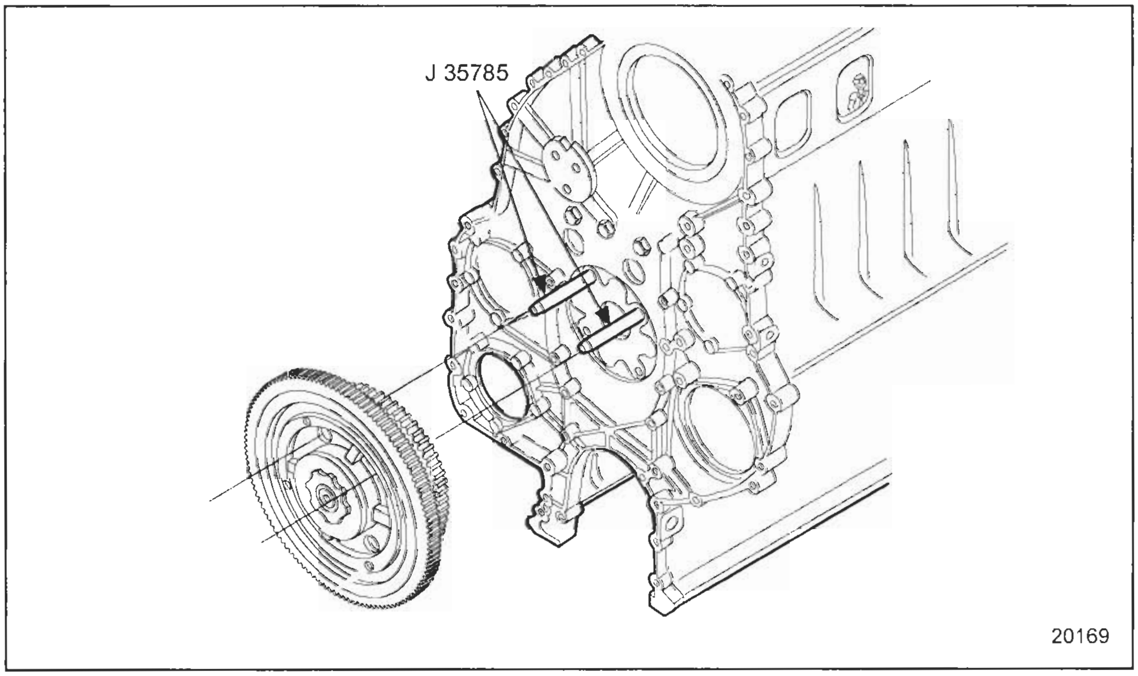


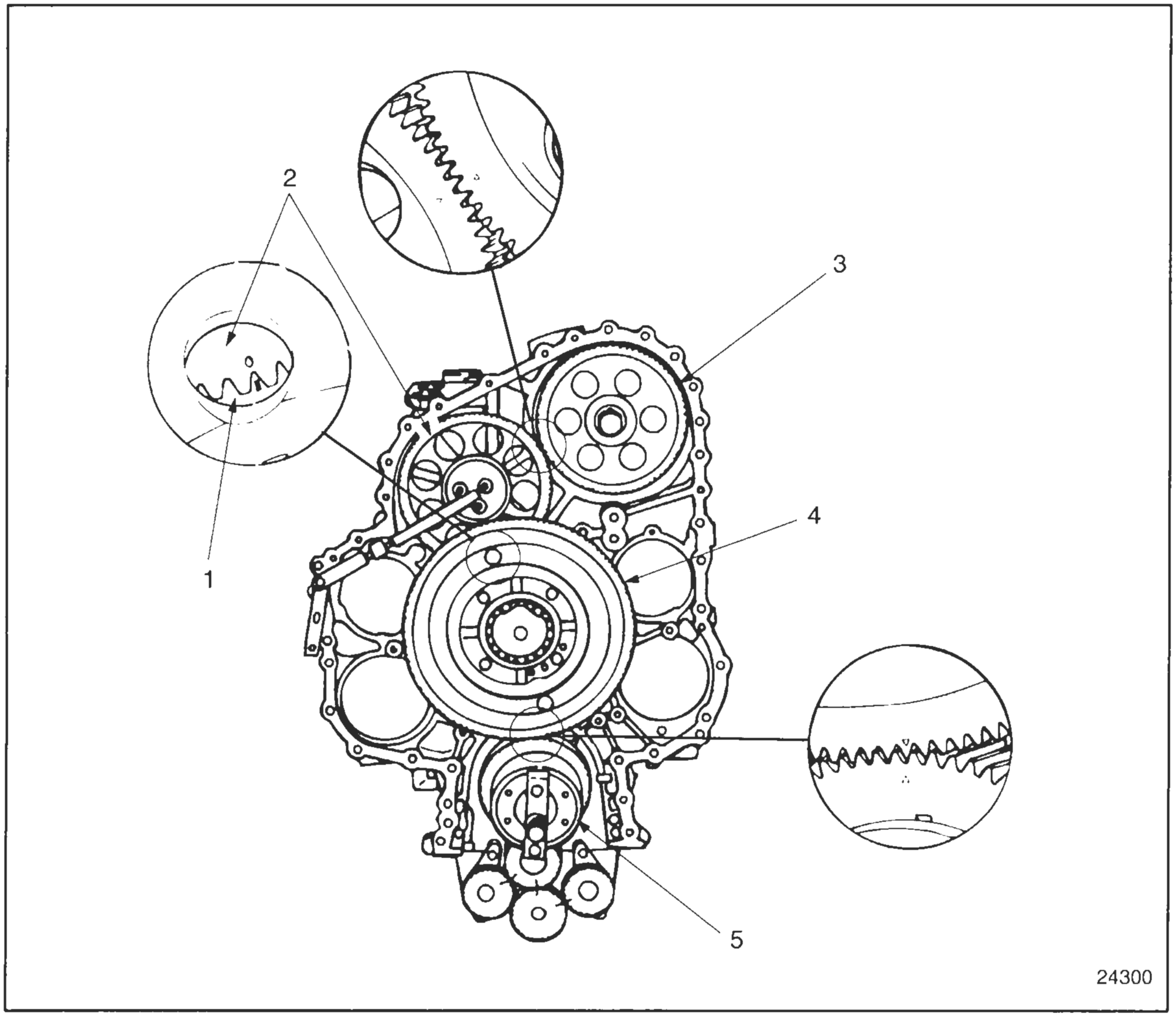
Figure 1–309 Bull Gear Stud Installation

3. Install the crankshaft protector, J 35994, to the oil seal contact area of the crankshaft.

NOTE:
The crankshaft protector, J 35994, will protect the crankshaft seal surface when installing the bull gear and camshaft idler gear assembly to the cylinder block.

4. Install the bull gear and camshaft idler gear assembly to the guide studs in the cylinder block.

5. Bar the engine over until the timing mark on the crankshaft timing gear is at the 12 o'clock position. See Figure 1–310.



1. Idler Gear, Camshaft
2. Idler Gear, Adjustable
3. Drive Gear, Camshaft
4. Bull Gear
5. Timing Gear, Crankshaft

Figure 1–310 Engine Gear Train and Timing Marks

6. Align the timing marks on the camshaft drive gear and the adjustable idler gear as shown. See Figure 1–310.
7. Slide the bull gear and camshaft idler gear assembly towards the engine, but do not engage any of the gears on the engine.
8. Looking through the access hole in the bull gear, align the timing marks on the adjustable idler gear and the camshaft idler gear as shown. See Figure 1–310.

9. Check the timing marks on the bull gear and crankshaft timing gear to ensure they will align when the bull bear assembly is seated in the cylinder block.

NOTE:
The injector and valve spring pressures will not allow easy rotation of the camshaft and adjustable idler gears. Therefore, it may be necessary to remove the rocker arm and shaft assemblies to facilitate aligning all three sets of timing marks. Refer to section 1.3.2.

10. When all three sets of timing marks are aligned, slide the bull gear and camshaft idler gear towards the engine completely and seat it in the recess in the gear case and cylinder block.

NOTICE:
Use care when installing the bull gear and camshaft idler gear assembly to prevent damaging the crankshaft oil seal contact surface.

11. Working through the lightening holes in the bull gear, install two of the bull gear assembly mounting bolts through the hub and into the cylinder block. Tighten the bolts finger tight.
12. Remove the two bull gear guide studs.
13. Install the remaining two bull gear assembly mounting bolts. Tighten all four mounting bolts to 101–116 N·m (75–86 lb·ft) torque. Work in a clockwise direction.
14. Check the timing marks on the gears to ensure the gear train is properly timed. See Figure 1–310.
15. Check the gear lash for all of the gears that mate with the bull gear and camshaft idler gear. Refer to section 1.21.
16. Install the gear case cover. Refer to section 1.10.3
17. Check bull gear to accessory drive gear lash. Refer to section 1.21.2.1.

1.26 CRANKSHAFT TIMING GEAR AND TIMING WHEEL

The crankshaft timing gear is a helical gear that is indexed to the crankshaft by a key and is pressed onto the end of the crankshaft. See Figure 1–311.

The Series 50 Engine crankshaft timing gear can be identified by a groove on the outside of the gear face.

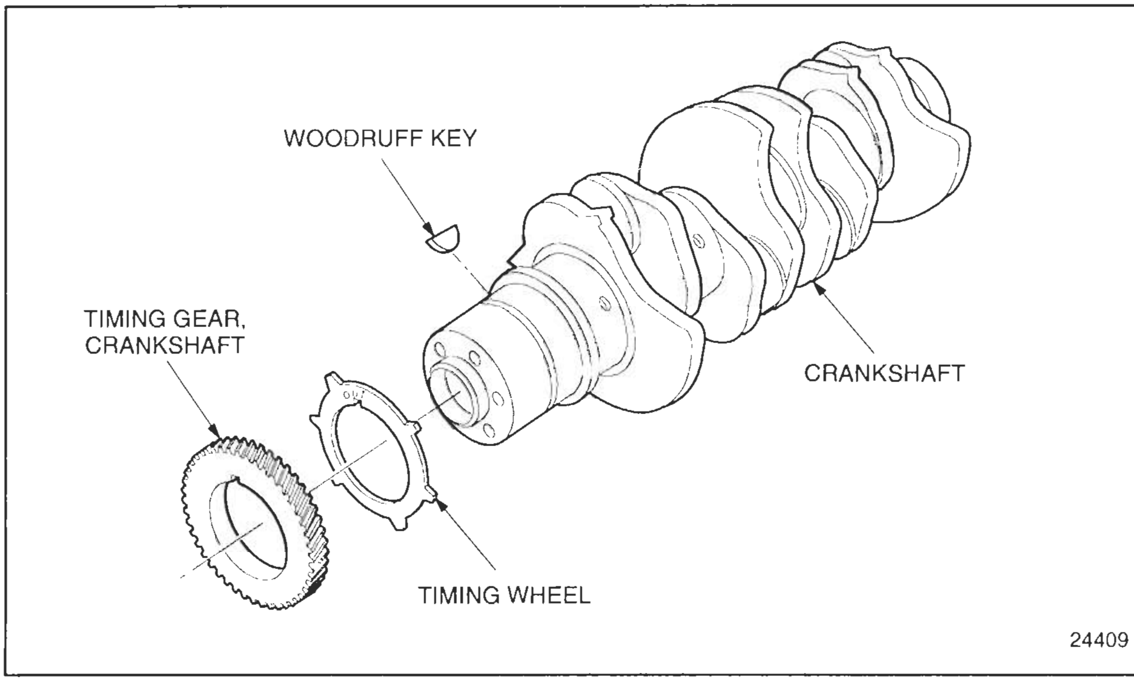


Figure 1–311 Crankshaft Timing Gear and Related Parts

The crankshaft timing gear directly drives the bull gear and oil pump drive gear. The bull gear drives the various accessories, and drives the camshaft through the idler gear. See Figure 1–312.

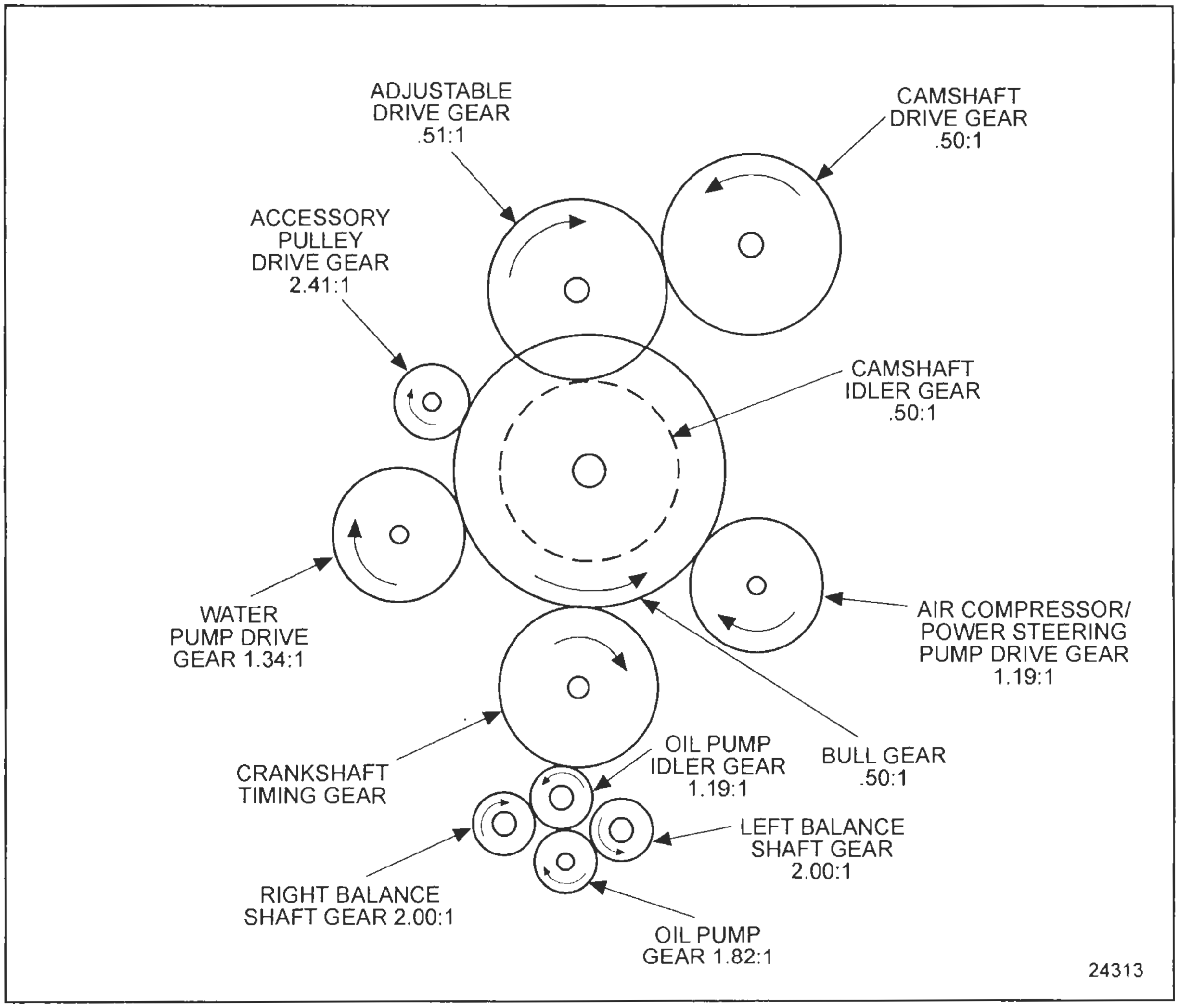


Figure 1–312 Engine Gear Train

A timing wheel is installed on the crankshaft directly behind the crankshaft timing gear. The timing wheel is indexed to the crankshaft by the same key as the crankshaft timing gear, and is retained to the crankshaft by the crankshaft timing gear. The timing wheel is marked with the word OUT on the outboard side, and should be installed with this mark facing you as you install the wheel. See Figure 1-313.

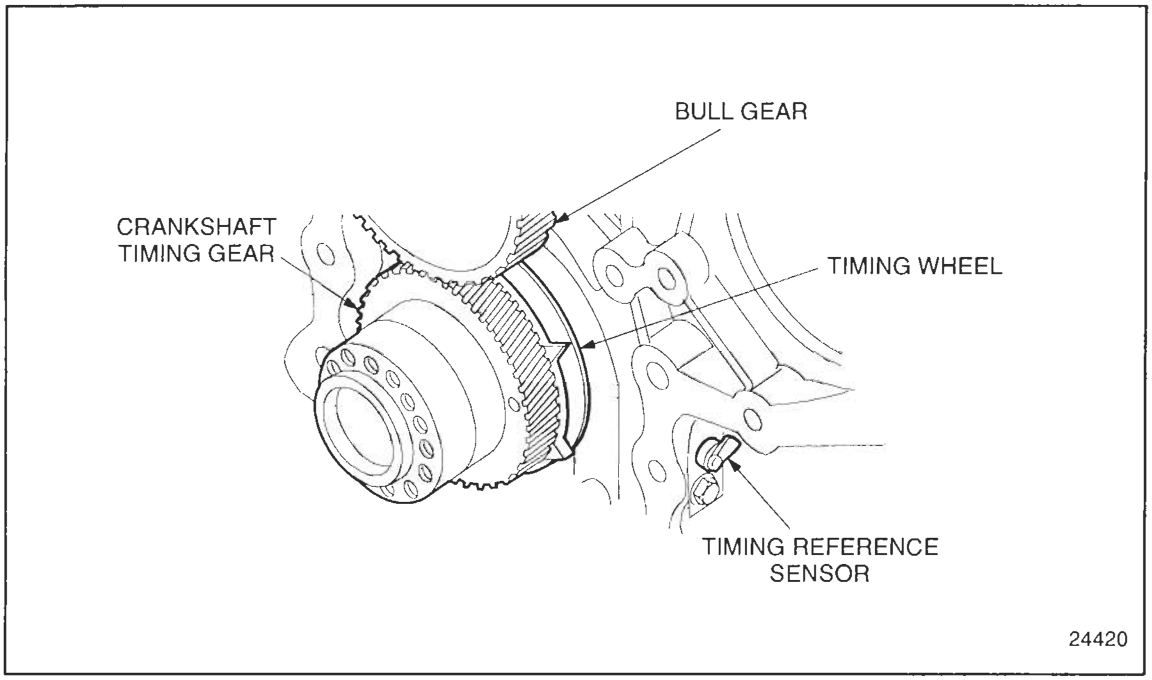


Figure 1–313 Crankshaft Timing Gear and Related Parts Location

The timing wheel induces a voltage signal in the Timing Reference Sensor (TRS), as the teeth of the pulse wheel passes by the TRS. This signal is sent to the Electronic Control Module (ECM) as each cylinder reaches 10° before top-dead-center.

Since the crankshaft and camshaft must be in time with each other, a series of timing marks are stamped or etched on the faces of the gears in the gear train. Refer to section 1.21.2.1 for gear train timing information. The balance shafts and crankshaft must also be in time with each other.

The crankshaft timing gear is lubricated by splash from the engine oil pan, and excess oil returning to the oil pan from the other gears.

1.26.1 Repair or Replacement of Crankshaft Timing Gear and Timing Wheel

To determine if repair or replacement of the crankshaft timing gear and timing wheel are necessary, perform the following procedure. See Figure 1–314.

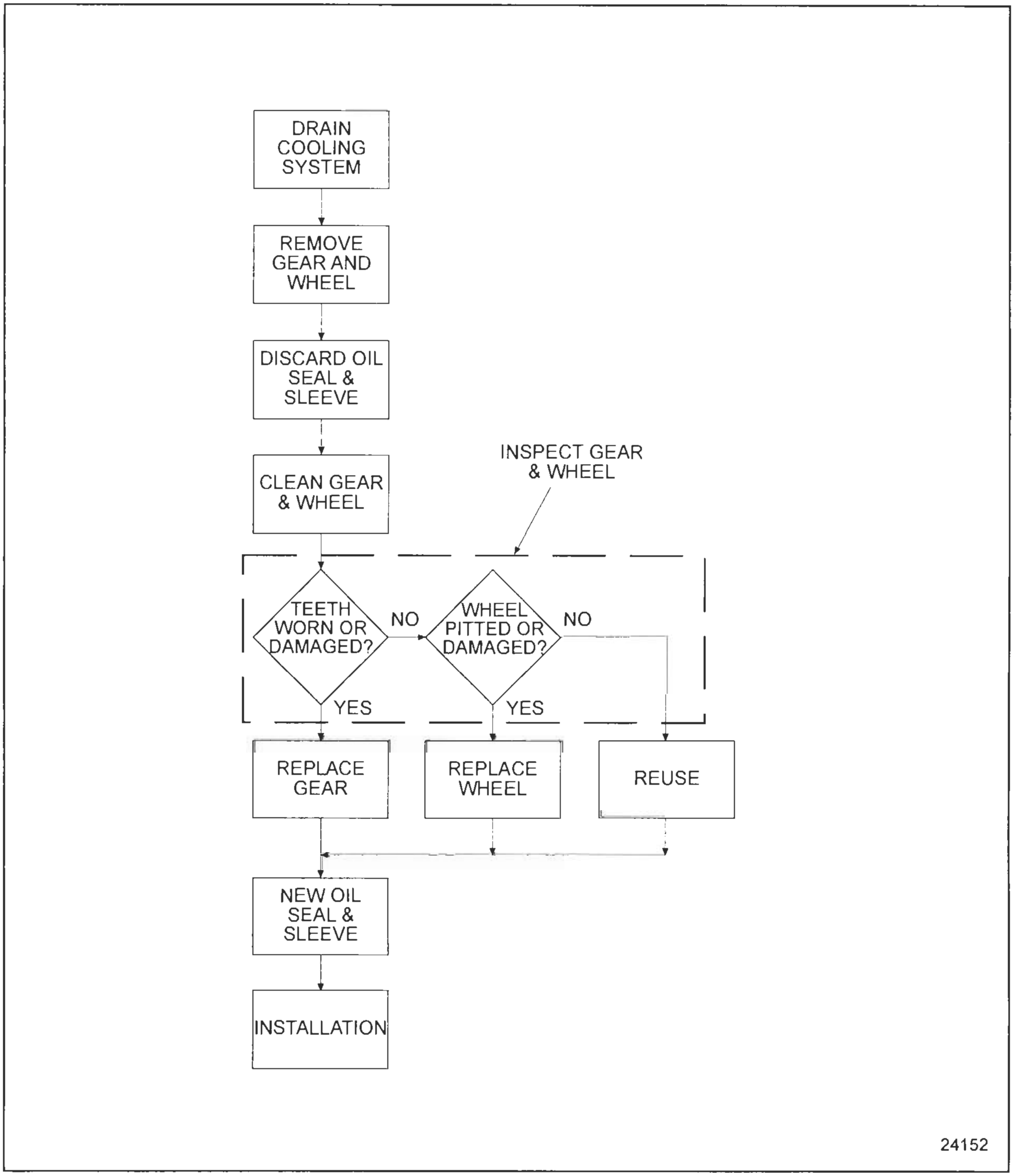


Figure 1–314 Flowchart for Repair or Replacement of Crankshaft Timing Gear and Timing Wheel

1.26.2 Removal of Crankshaft Timing Gear and Timing Wheel Removal

Remove the gear and the timing wheel as follows:

1. Drain the cooling system. Refer to section 13.5.4.
2. Remove the radiator to engine coolant hoses.
3. Remove the timing reference sensor. Refer to section 2.15.2.
4. Remove components as necessary to gain access to the gear case cover.
5. Remove the gear case cover. Refer to section 1.10.2.
6. If an oversize crankshaft front oil seal sleeve is used, peen the outside diameter of the sleeve until it stretches sufficiently and slip the sleeve off of the crankshaft. Discard sleeve.
7. Remove the balance assembly. Refer to section 1.27.2.

NOTICE:
Use care when removing the bull gear assembly. To prevent damaging the crankshaft oil seal contact surface, use Crankshaft Protector, J 35994 on end of crankshaft or oil leaks may result.

8. Remove the bull gear and camshaft idler gear assembly. Refer to section 1.25.2.

9. Using two of the crankshaft pulley bolts, secure the base post, J 35642–1, part of tool kit J 35642, to the end of the crankshaft. Tighten the bolts to 190–203 N·m (140–150 lb·ft) torque. See Figure 1–315.

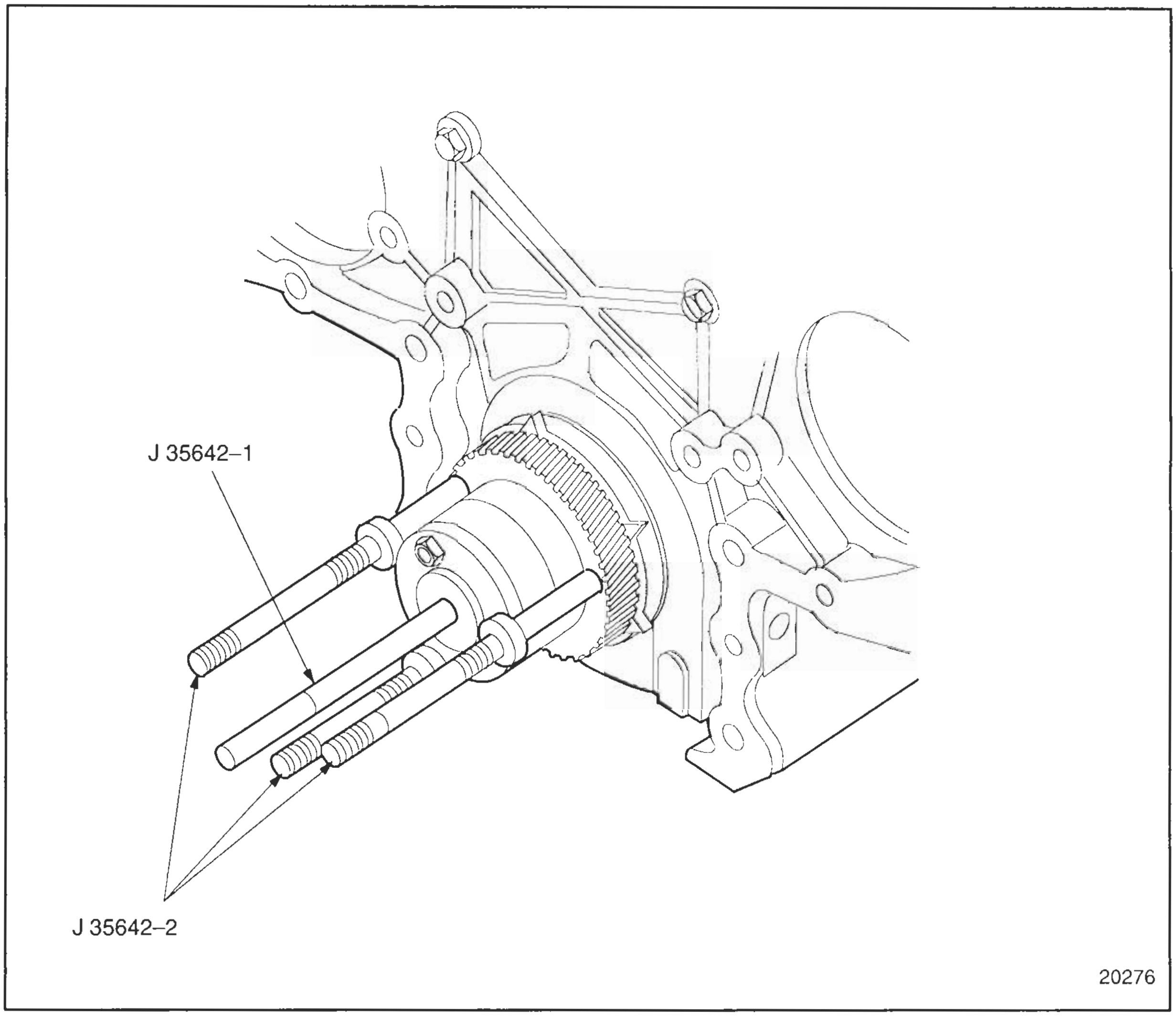


Figure 1–315 Installation of Crankshaft Timing Gear Removal Tools

NOTE:
The crankshaft removal values are shown with the crankshaft installed in the engine. The crankshaft timing gear may be removed with the crankshaft in or out of the engine.

10. Thread the three legs, J 35642–2, part of tool kit J 35642, into the three threaded holes in the crankshaft timing gear. Tighten the legs so they are snug.

11. Slide the hydraulic ram of portable press, J 35951–175, over the center rod of base post, J35642–1 part of tool kit J 35642, and all the way to the base. See Figure 1–316.

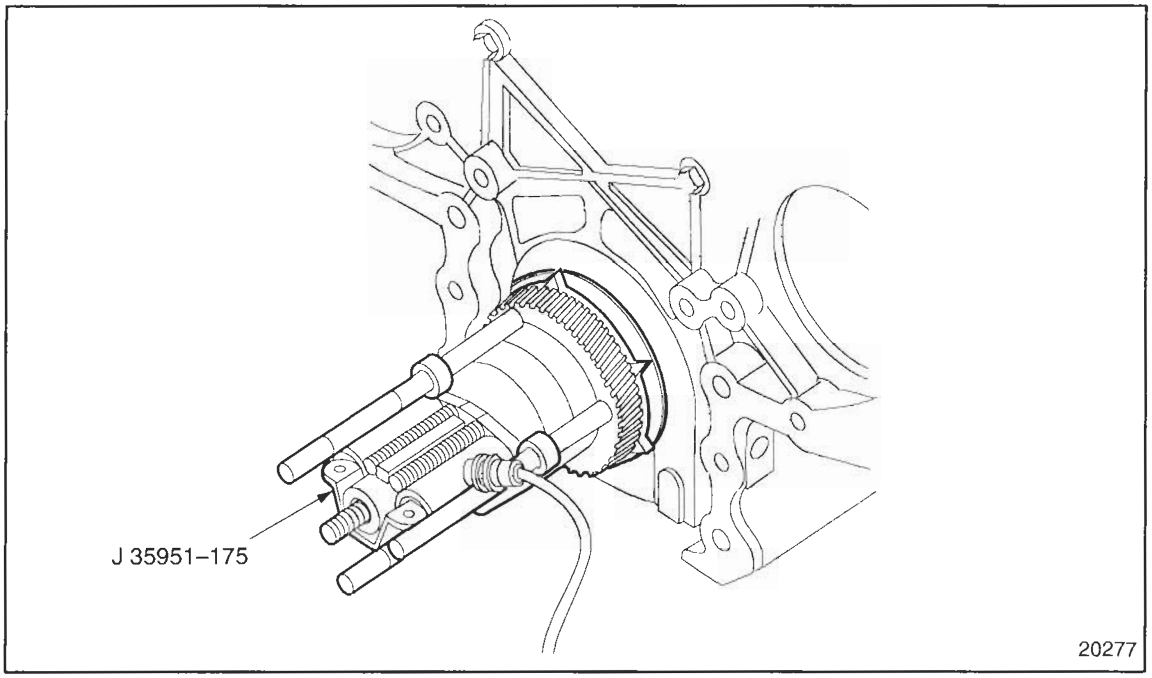


Figure 1–316 Hydraulic Ram Installation

12. Install the Pressure Plate, J 35642-4, to the three legs, J 35642-2, both part of tool kit J 35642. See Figure 1-317.

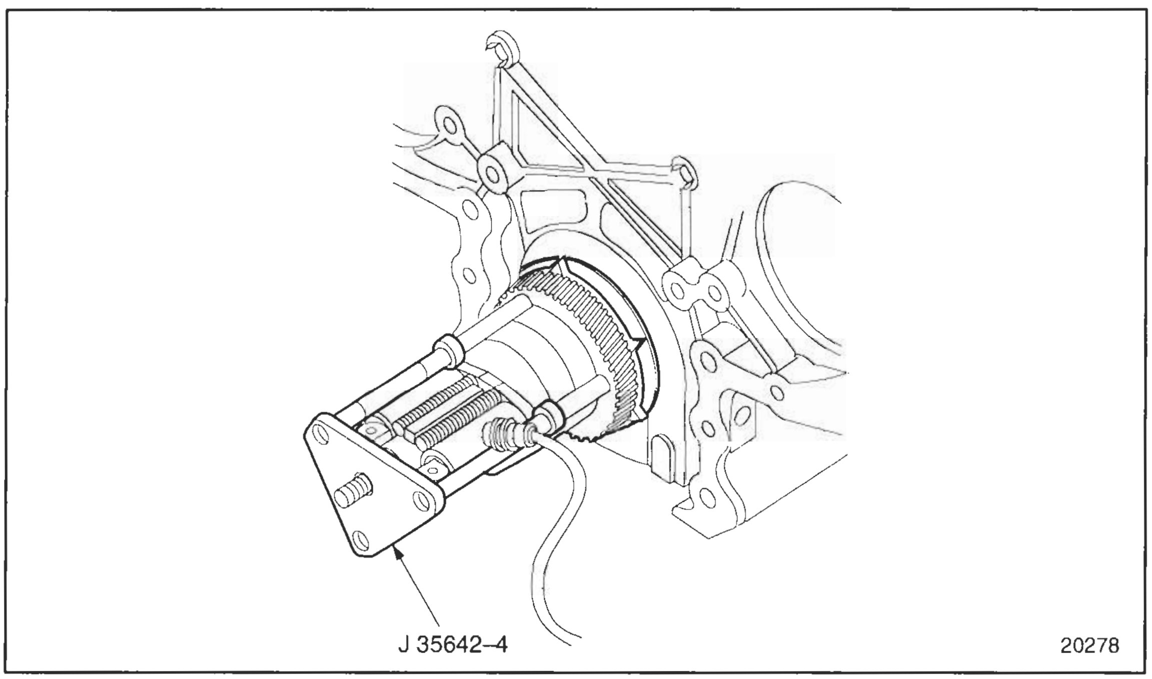


Figure 1–317 Pressure Plate Installation

13. Install the three retaining nuts to the legs. Tighten the nuts to the pressure plate. Tighten the nuts until they are snug. See Figure 1-318.

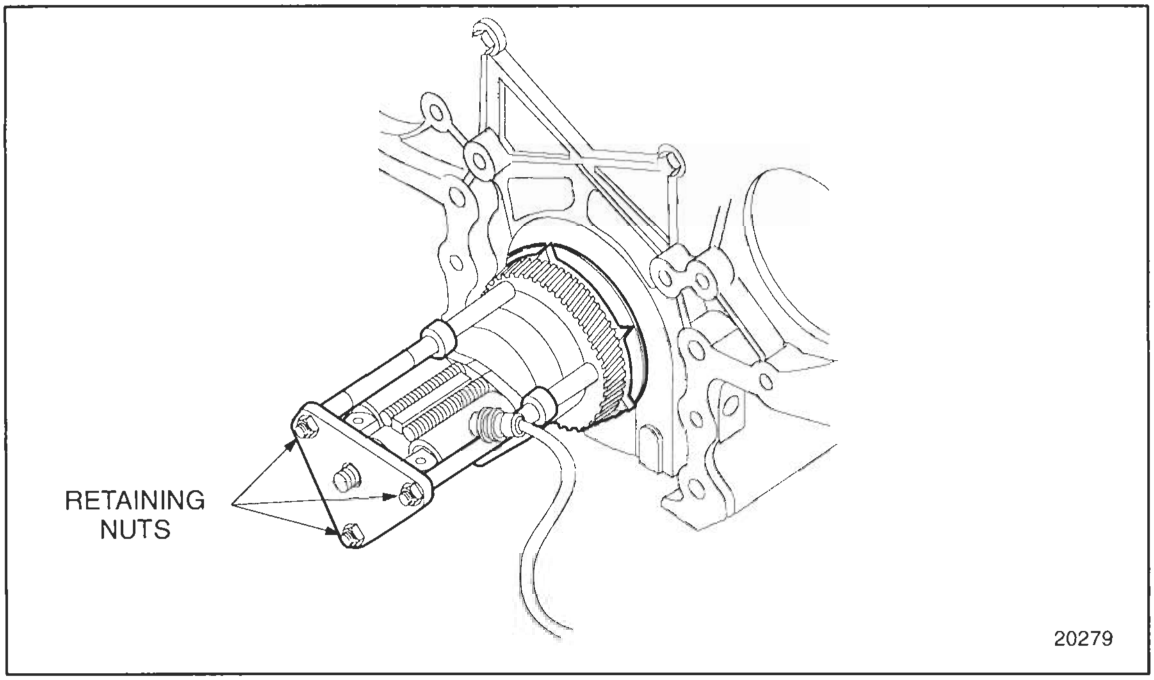


Figure 1–318 Retaining Nuts Installation

14. Close the valve on the hydraulic pump of portable press J 35951–175. Pump the lever to build pressure and remove the crankshaft timing gear. See Figure 1–319.

NOTE:
Considerable pressure is required to remove the crankshaft timing gear. Due to manufacturer's tolerances, it may take as much as 80 kN (9 tons) of force to remove the crankshaft timing gear.

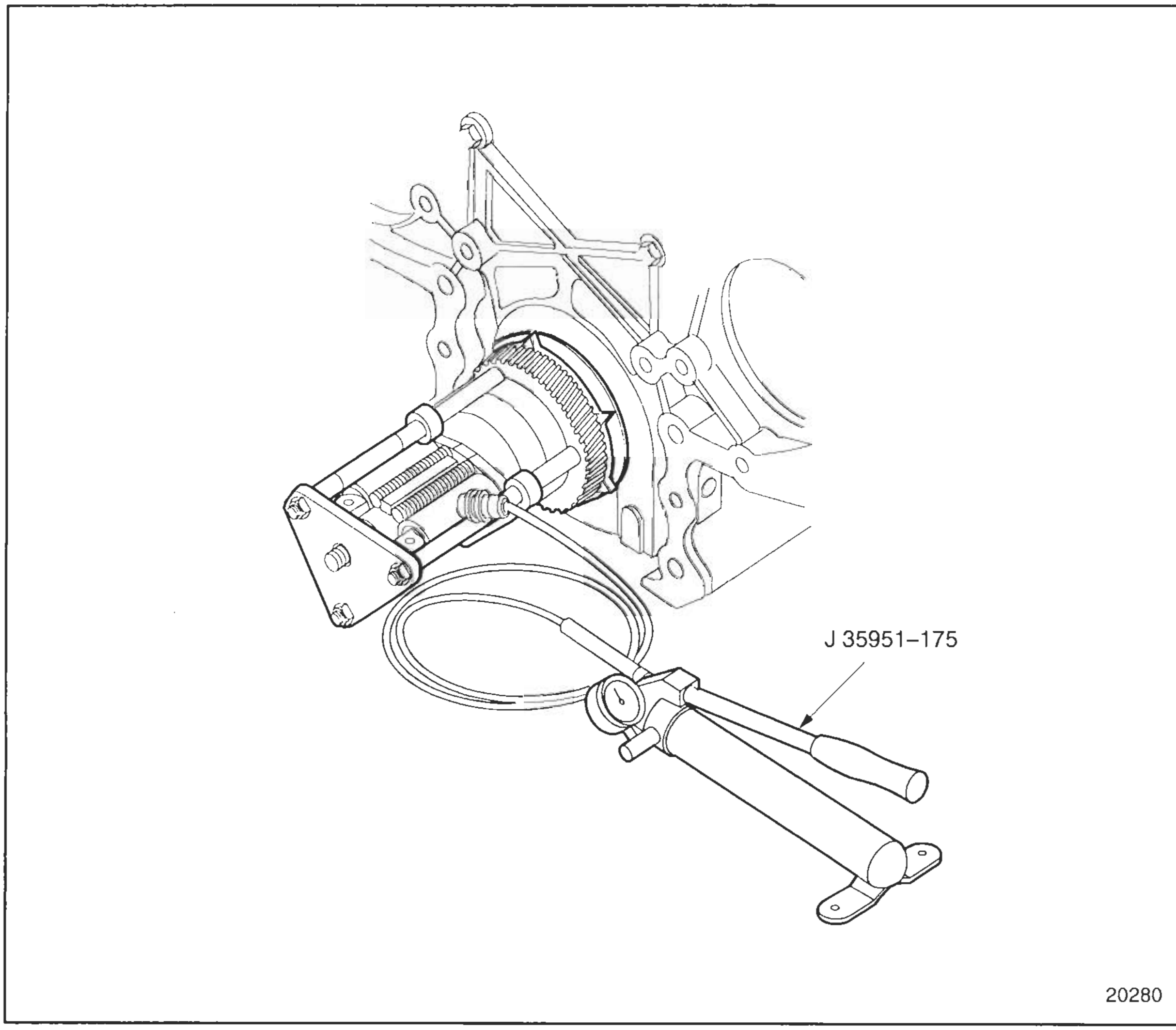


Figure 1–319 Crankshaft Timing Gear Removal

15. Remove the tools from the engine and timing gear as follows:
    [a] Open the valve on the hydraulic pump of portable press, J 35951-175, to relieve the pressure.
    [b] Loosen and remove the three retaining nuts on the legs, J 35642-2, part of tool kit J 35642, against the pressure plate.
    [c] Remove the pressure plate, J 35642-2, part of tool kit J 35642.
    [d] Remove the hydraulic ram of portable press, J 35951-175.
    [e] Loosen and remove the three legs, J 35642-2, part of tool kit J 35642.
    [f] Loosen and remove the two crankshaft pulley bolts and remove the base post, J 35642-1, part of tool kit J 35642.

NOTICE:
Care should be exercised when removing the timing wheel. Do NOT use sharp tools to pry on the timing wheel. Damage to the crankshaft seal contact surface may cause oil leaks.

16. Slide the timing wheel off the end of the crankshaft.

NOTE:
The timing wheel is a slip fit to the crankshaft, and no special tools are necessary for removal. A three-jaw adjustable puller, however, may be necessary.

1.26.2.1 Inspection of Crankshaft Timing Gear and Timing Wheel

Inspect the crankshaft timing gear and timing wheel as follows:

1. Clean the crankshaft timing gear and timing wheel with clean fuel oil.

CAUTION:
To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

2. Dry all parts with compressed air.
3. Examine the gear teeth of the crankshaft timing gear for evidence of scoring, pitting, or excess wear.

4. If gear teeth are damaged or worn, install a new gear.

NOTE:
If gear teeth are damaged or severely worn, also check the other gears in the gear train. Refer to section 1.21.

5. Examine the timing wheel for evidence of pitting and the gear teeth for bending or damage.
6. If wheel is pitted or gear teeth damaged, replace timing wheel.

1.26.3 Installation of Crankshaft Timing Gear and Timing Wheel

Install the crankshaft timing gear and timing wheel as follows:

1. Install the base post, J 35642–1, part of tool kit J 35642, to the end of the crankshaft, using two crankshaft pulley retaining bolts. Tighten the bolts to 190–203 N·m (140–150 lb·ft) torque. See Figure 1–320.

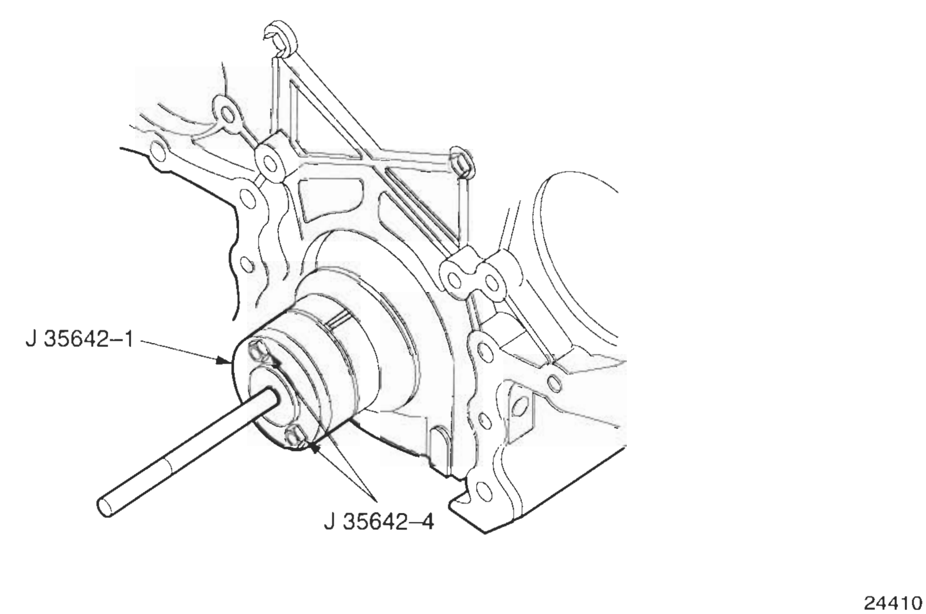


Figure 1–320 Base Post Installation

2. If removed, install the key to the keyway. Tap the key with a plastic mallet or brass hammer to seat. See Figure 1-321.

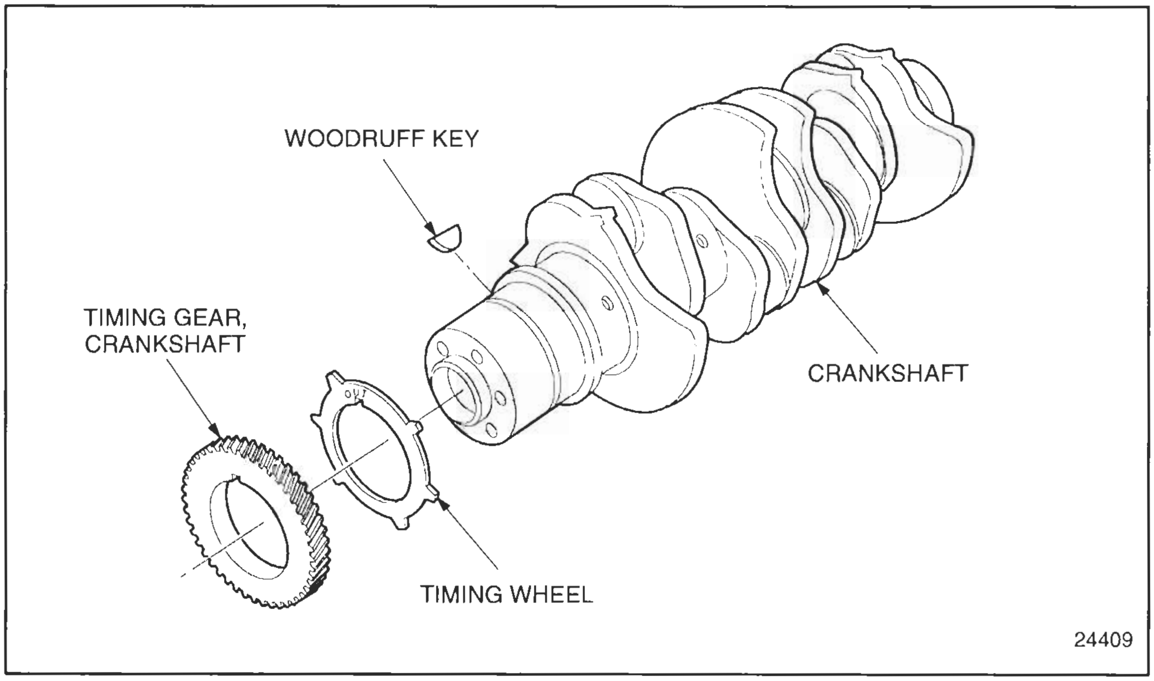


Figure 1–321 Non–Lock Key Installation

3. Index the keyway of the timing wheel with the key in the crankshaft. Slide the timing wheel onto the crankshaft, with the word OUT on the timing wheel facing you, as far as it will go without forcing it. See Figure 1-322.

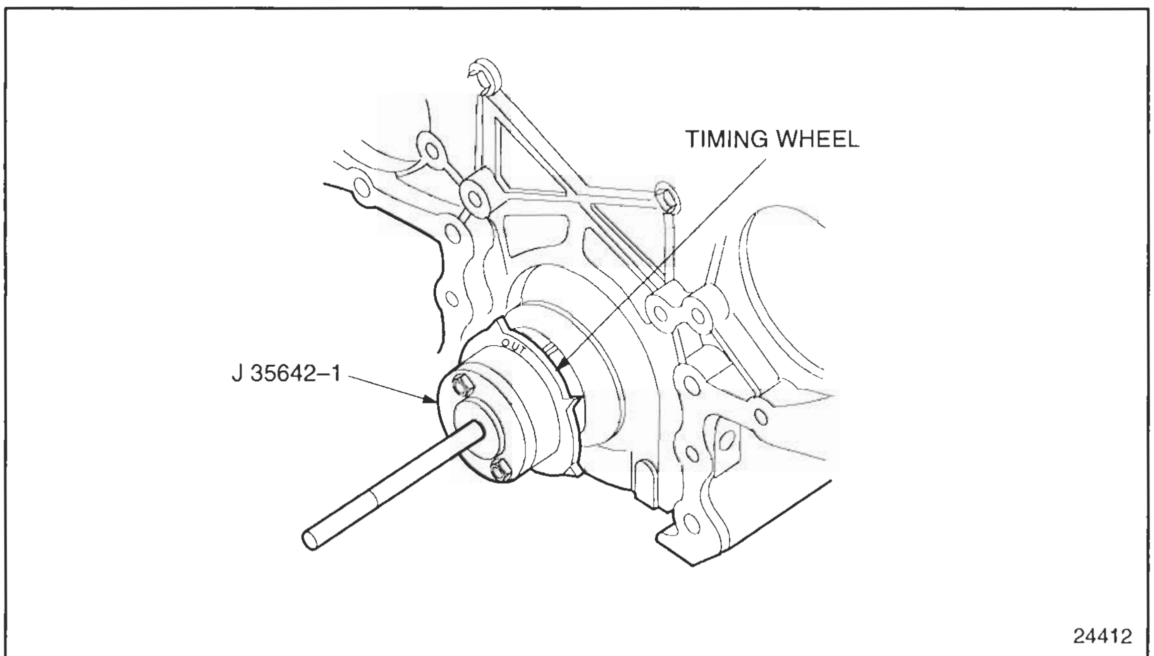


Figure 1–322 Timing Wheel Installation

4. Coat the bore of the crankshaft timing gear with a film of Lubriplate.
5. Index the keyway of the crankshaft timing gear with the Woodruff key in the crankshaft. Tap the gear with a plastic hammer or fiber mallet, to ensure that the key is started in the keyway. See Figure 1–323.

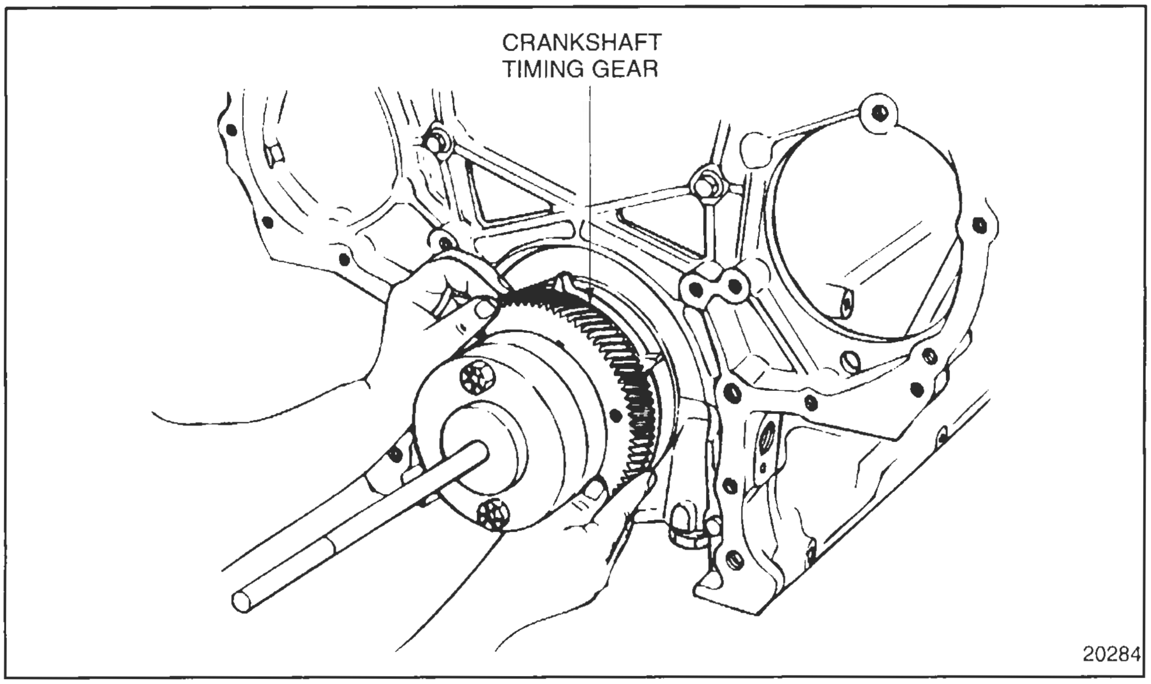


Figure 1–323 Crankshaft Timing Gear Indexing

6. Install the three legs of timing gear puller, J 35642–2, part of tool kit J 35642, to the threaded holes in the crankshaft timing gear. Tighten the three legs, but do not torque. See Figure 1–324.

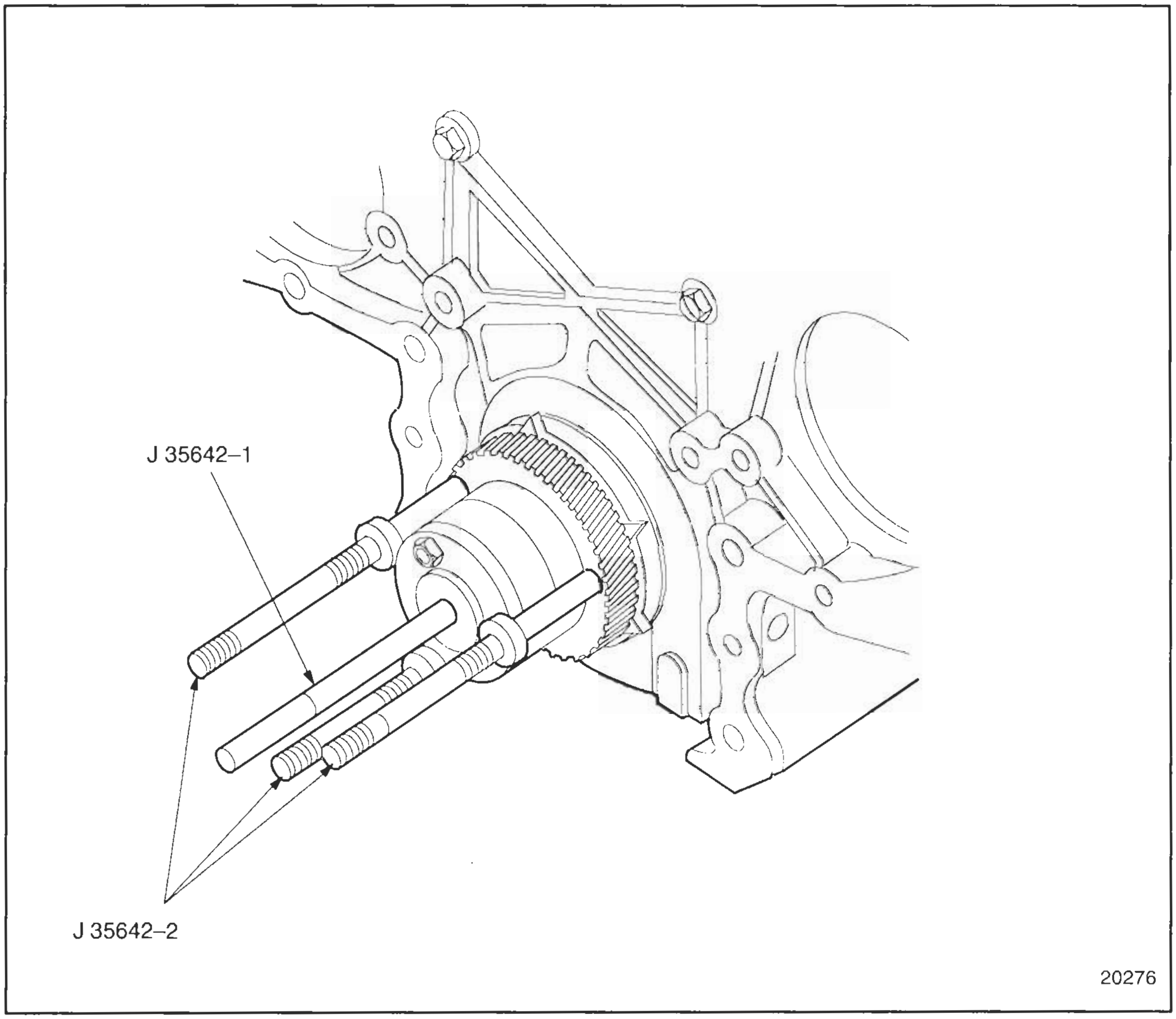


Figure 1–324 Puller Leg Installation

7. Install the pressure plate, J 35642–4, part of tool kit J 35642, to the three pulley legs. Seat the pressure plate against the flanges on the puller legs. See Figure 1–325.

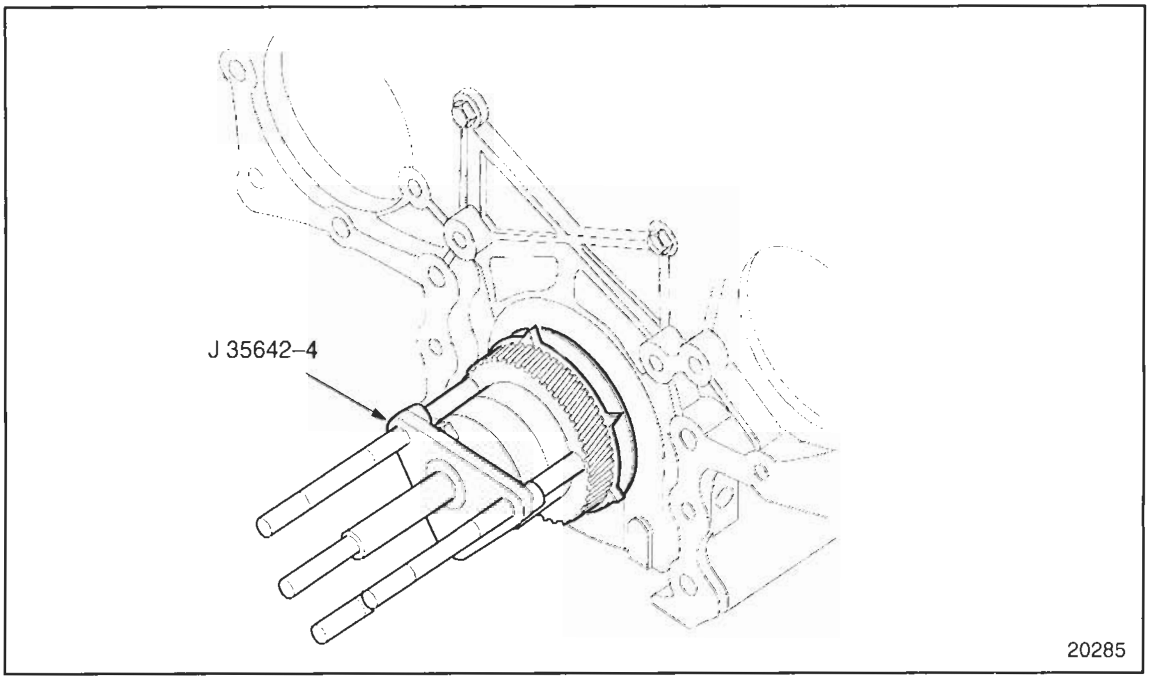


Figure 1–325 Pressure Plate Installation

8. Install the three retaining nuts to the puller legs. Thread the nuts past the first set of threads on the legs. Slide the nuts past the unthreaded portion of the shafts, and engage the second set of threads. Tighten but do not torque the retaining nuts. See Figure 1–326.

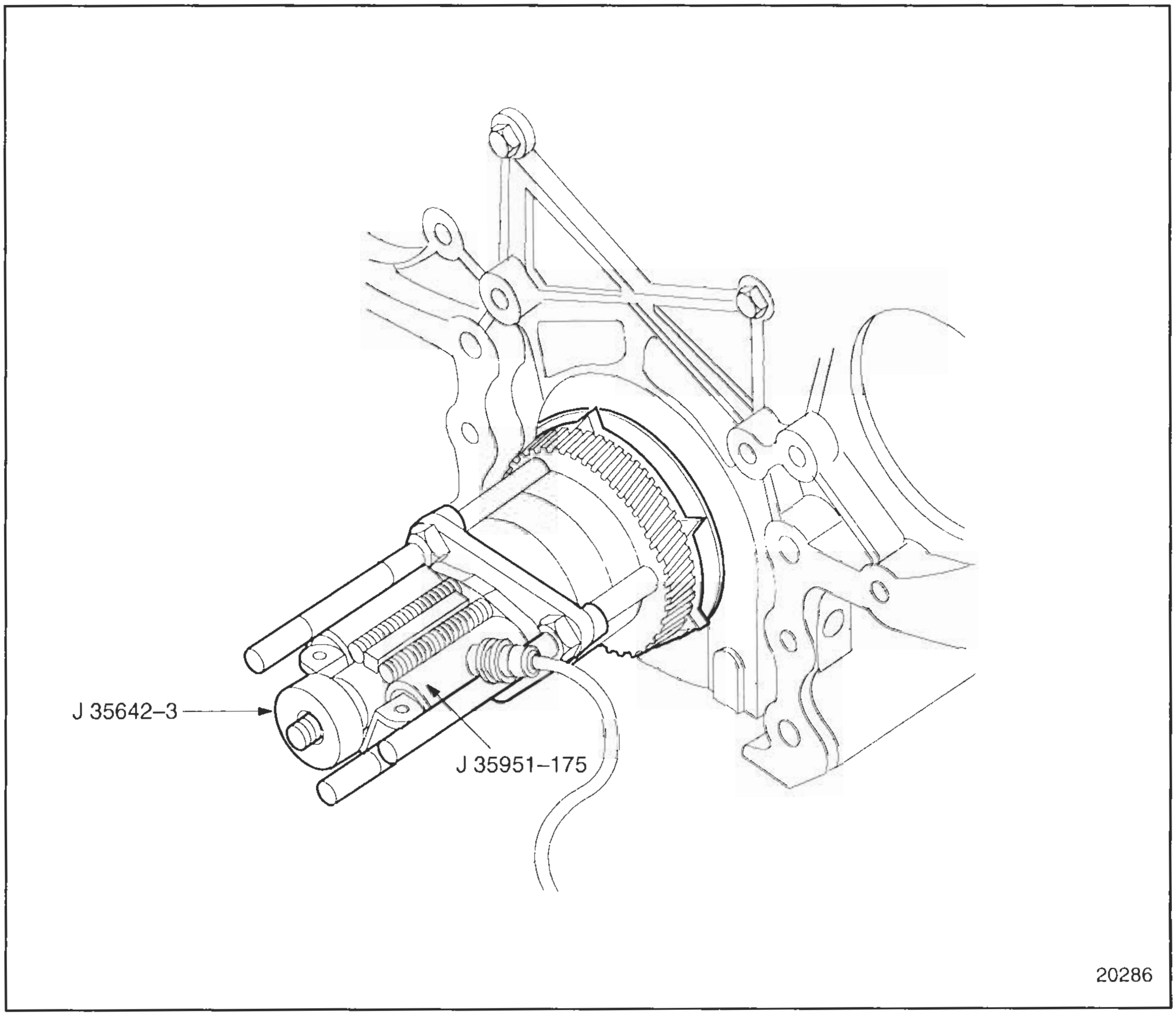


Figure 1–326 Crankshaft Timing Gear Installation Tools

9. Install the hydraulic ram to the base post rod. See Figure 1–326.
10. Install the stop nut, J 35642–3, part of tool kit J 35642, to the end of the base post threaded rod. Tighten the stop nut.

11. Close the valve on the hydraulic pump, J 35951–175. Work the pump handle to supply hydraulic pressure to the ram. Make sure that the slot in the crankshaft timing gear indexes with the key in the crank. Pump until the crankshaft timing gear is seated firmly against the timing wheel and the timing wheel is seated firmly against the crankshaft flange. See Figure 1–327.

NOTE:
A minimum force of 30 kN (3.37 tons) must be obtained when pressing the gear on the crankshaft.

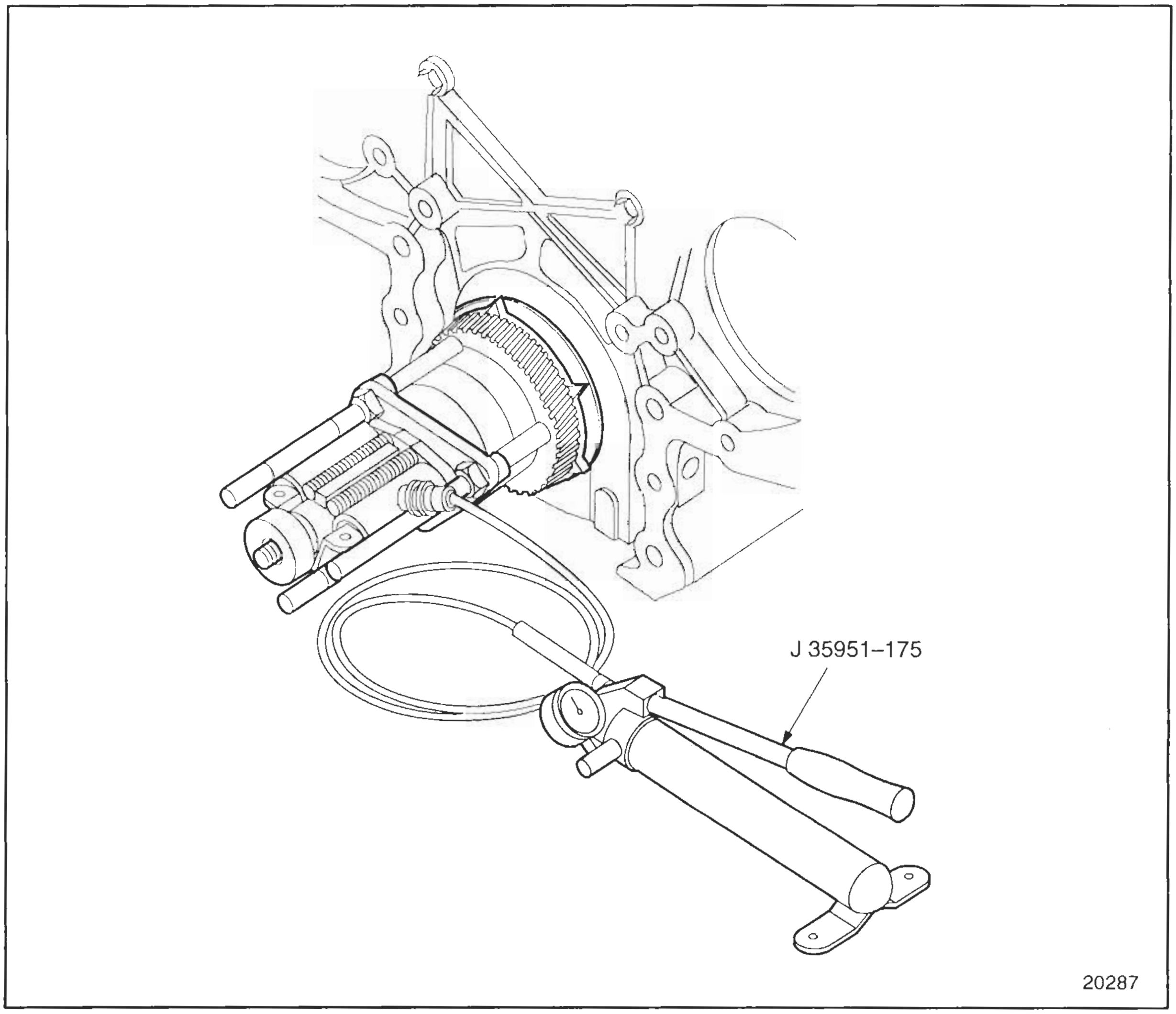


Figure 1–327 Crankshaft Timing Gear Installation

12. Remove the special tools as follows:
    [a] Open the valve on the hydraulic pump.
    [b] Remove the stop nut, J 35642-3, part of tool kit J 35642, from the end of the base post threaded rod.
    [c] Remove the hydraulic ram from the base post rod.
    [d] Remove the three retaining nuts from the puller legs of Timing gear puller, J 35642-2, part of tool kit J 35642.
    [e] Remove the pressure plate, J 35642-4, part of tool kit J 35642, from the three pulley legs.
    [f] Remove the three legs of timing gear puller, J 35642-2, part of tool kit J 35642, from the threaded holes in the crankshaft timing gear.
    [g] Remove the base post, J 35642-1, part of tool kit J 35642, and two crankshaft pulley retaining bolts from the end of the crankshaft.
13. Install the bull gear and camshaft idler gear assembly to the gear case. Refer to section 1.25.3.

NOTE:
Be sure to time the gears as instructed.

14. Install the balance assembly and outlet pipes. Refer to section 1.27.3.
15. Measure the gear lash between the crankshaft timing gear and oil pump drive gear. Refer to section 1.21.2.1.
16. Measure the lash between the crankshaft timing gear and the bull gear. Refer to section 1.21.2.1.
17. Install the gear case cover. Refer to section 1.10.3.
18. Install a new crankshaft seal and sleeve. Refer to section 1.8.5.
19. Install the timing reference sensor (TRS). Refer to section 2.16.3.
20. Install any components that were removed for access to the gear case cover.

1.27 BALANCE SHAFT AND OIL PUMP MECHANISM

The Series 50 Engines requires a system to smooth the vibrations that are inherent in all four stoke engines of inline, four cylinder configuration. Two counterweighted balance shafts rotate at twice the engine speed to cancel these forces. The balance mechanism is comprised of two gear driven balance shafts, the oil pump, oil suction and supply tubes, and the oil pressure relief and regulator valves.

1.27.1 Repair or Replacement of the Balance Shaft and Oil Pump Mechanism

To determine if repair or replacement of the balance shaft and oil pump mechanism is necessary, perform the following procedure. See Figure 1–328.

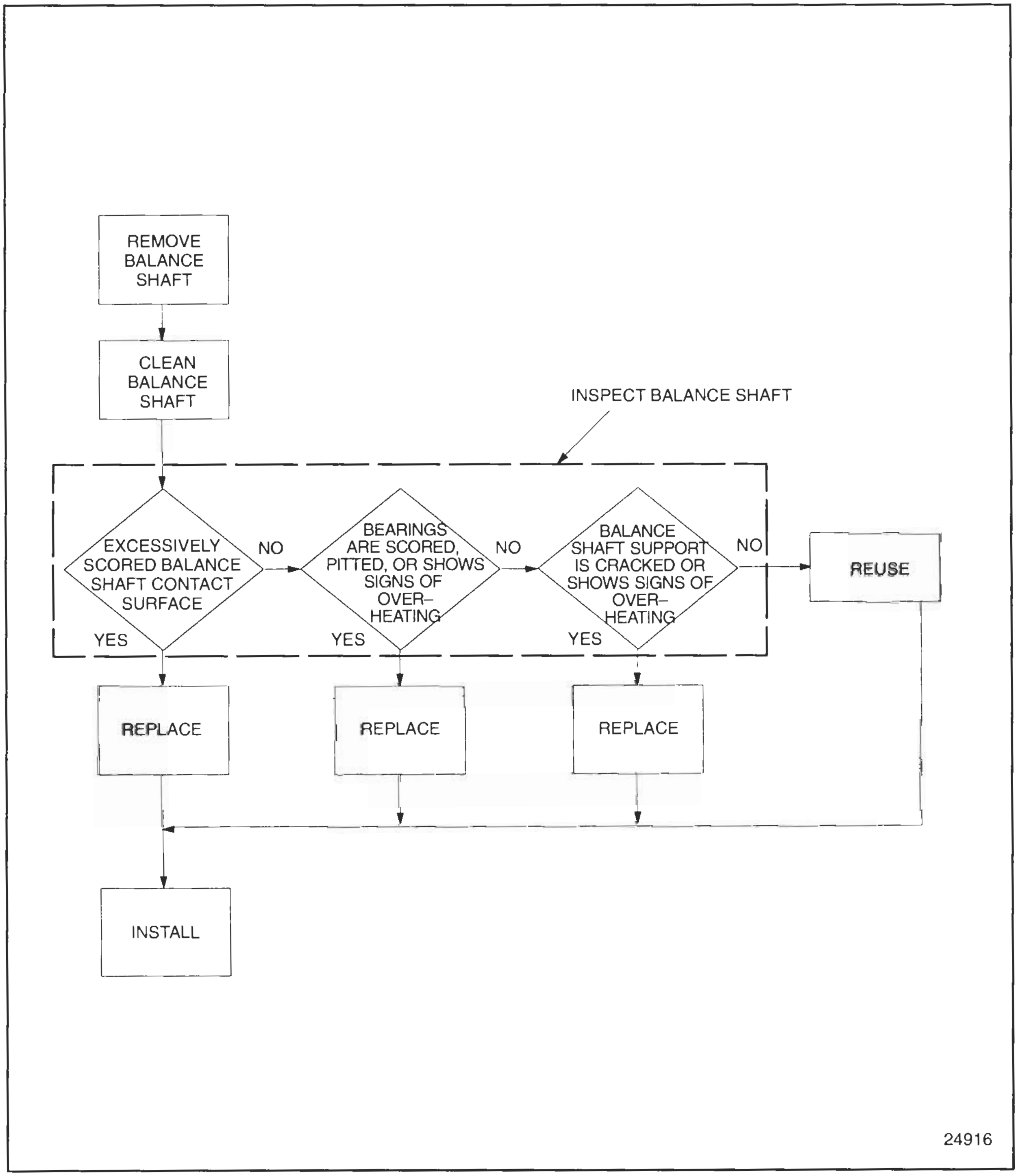


Figure 1–328 Flowchart for Repair or Replacement of the Balance Shaft and Oil Pump Mechanism

1.27.2 Cleaning and Removal of the Balance Shaft and Oil Pump Mechanism

Precleaning is not necessary.

Remove the balance shaft and oil pump mechanism as follows:

1. Set cylinder No. 1 at top dead center by barring the engine over until the piston reaches the top of the cylinder. The cylinder will then be at top-dead-center (TDC).
2. Drain the engine oil and remove the oil pan. Refer to section 3.9.2.
3. Unfasten the two M10 capscrew that fasten the oil suction tube braces to the balance support.
4. Unfasten the two M8 capscrew that attach the suction tube flange to the oil pump body and remove the suction tube assembly.
5. Install oil pump gear holding tool, J 39816. See Figure 1-329.

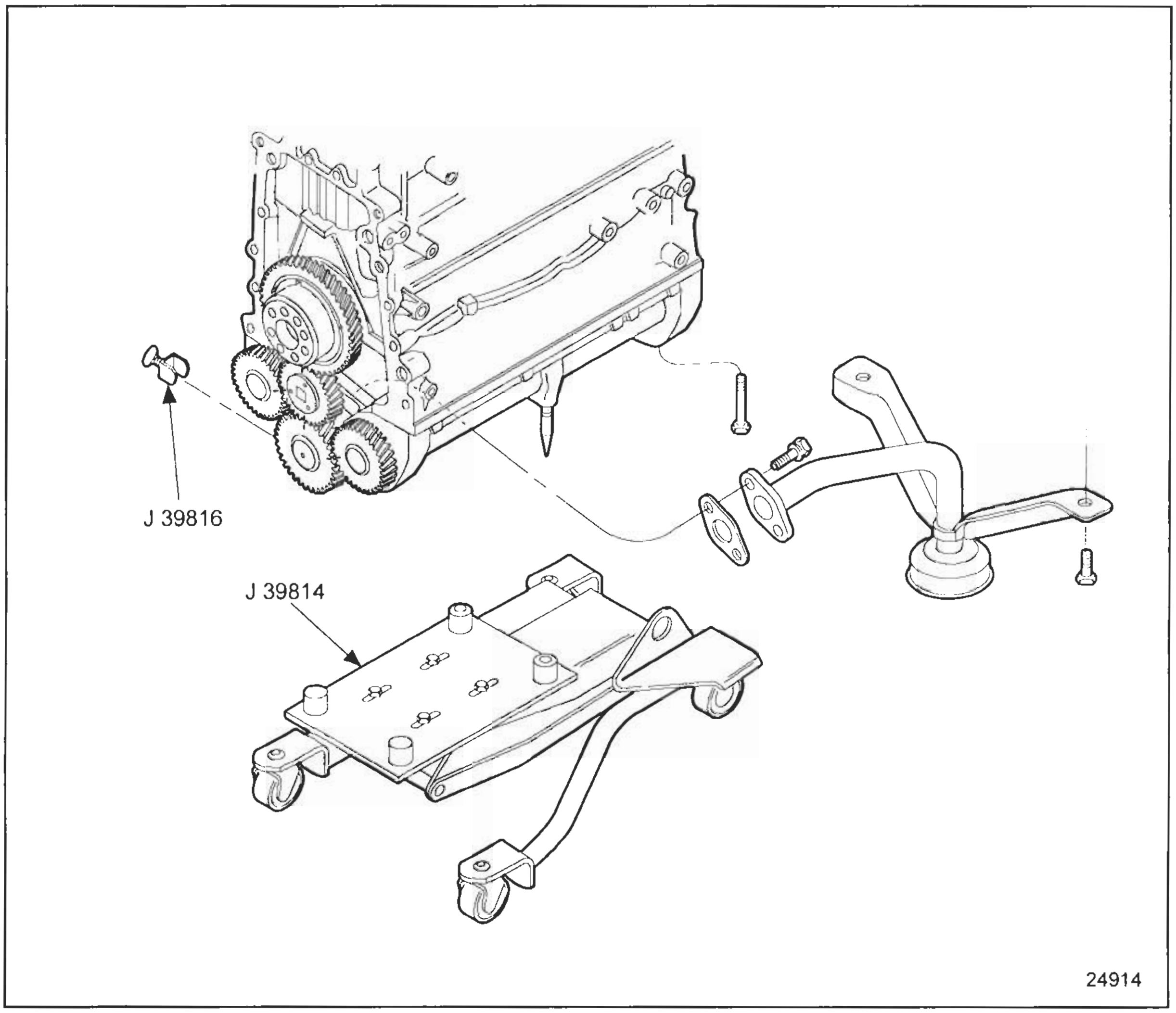
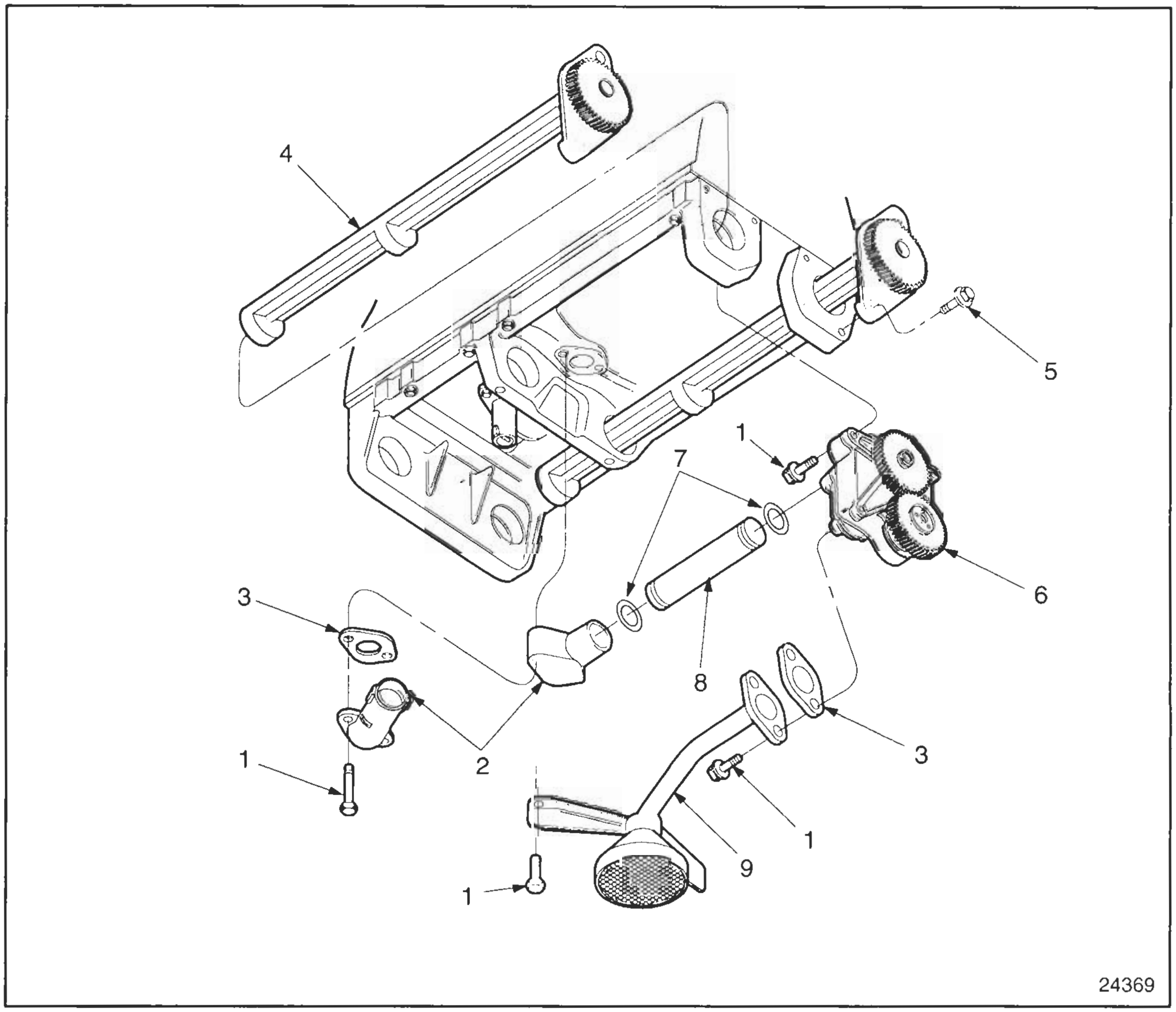


Figure 1-329 Oil Pump Gear Holding Tool

6. Support the balance assembly on the center and front bulkhead using tool, J 39814–A, and a transmission jack.
7. Remove the nine capscrews that fasten the balance assembly to the cylinder block and lower the assembly.
8. Lift the balance assembly from the transmission jack, turn it over and set it on a clean working surface using care not to damage the locating dowels.

Remove the oil pump as follows: See Figure 1–330.

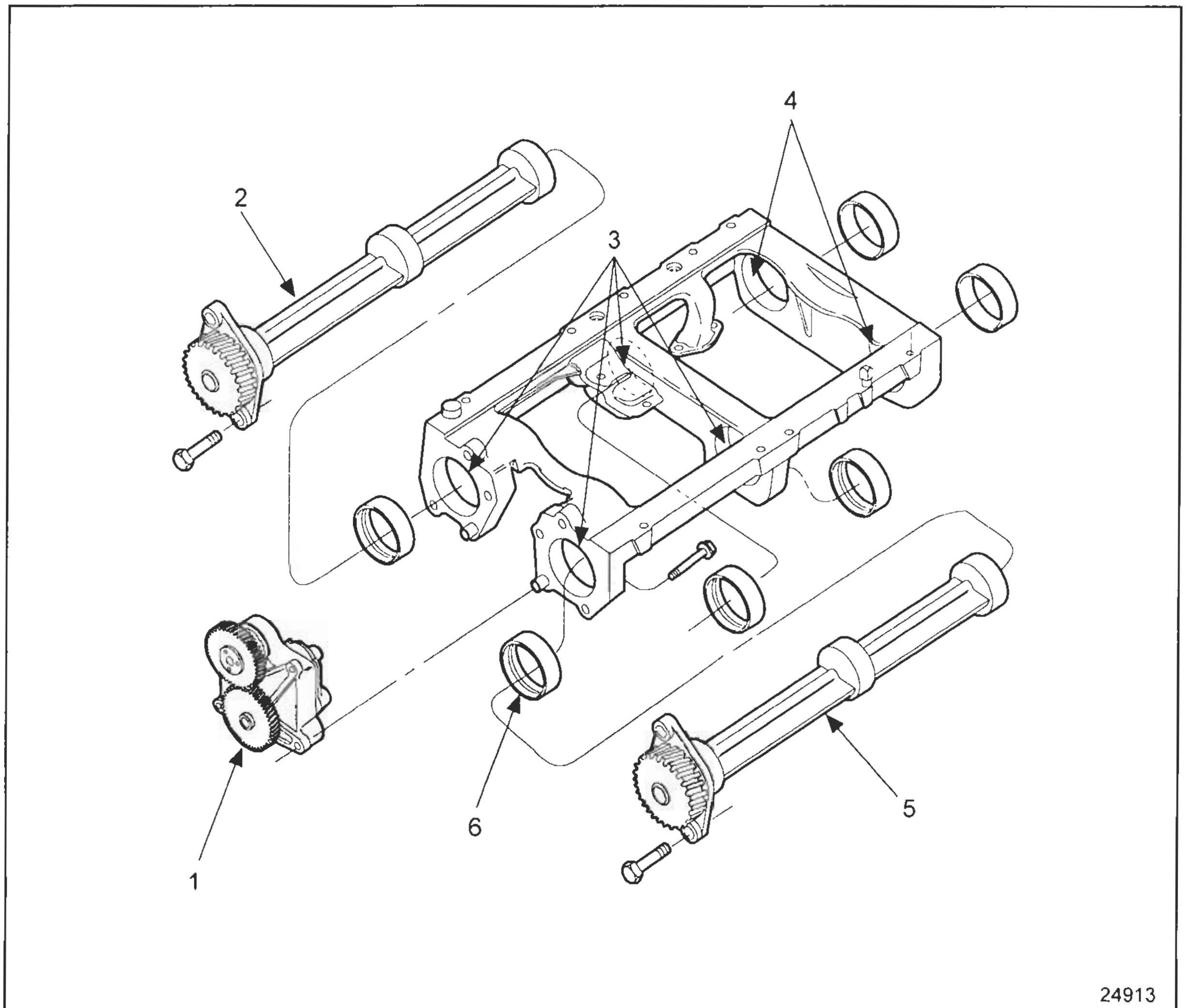


1. Bolt
2. Regulator Valve and Adaptor
3. Gasket
4. Balance Shaft Assembly
5. Thrust Plate Bolt
6. Oil Pump Assembly
7. O–rings
8. Oil Feed Tube
9. Pick–up Tube and Bracket

Figure 1–330 Oil Pump and Related Components Removal

1. Unfasten the four M8 capscrews that attach the oil pump to the balance support.
2. Loosen, but do not remove, the two M8 capscrews at each balance shaft thrust plate enough to allow the balance shaft to slide and create clearance for removal of the oil pump.
3. Remove the oil pump outlet tube and set it aside.

Remove the balance shaft as follows: See Figure 1–331.



1. Oil Pump
2. Balance Shaft
3. Wide Bushings
4. Narrow Bushings
5. Balance Shaft
6. Balance Shaft Bushing

Figure 1–331 Balance Assembly Disassembly

Remove the balance shaft bushings as follows:

1. Attach the balance shaft removal tool, J 39817, to the rearmost bearing journal face of the left side balance shaft. See Figure 1–332.

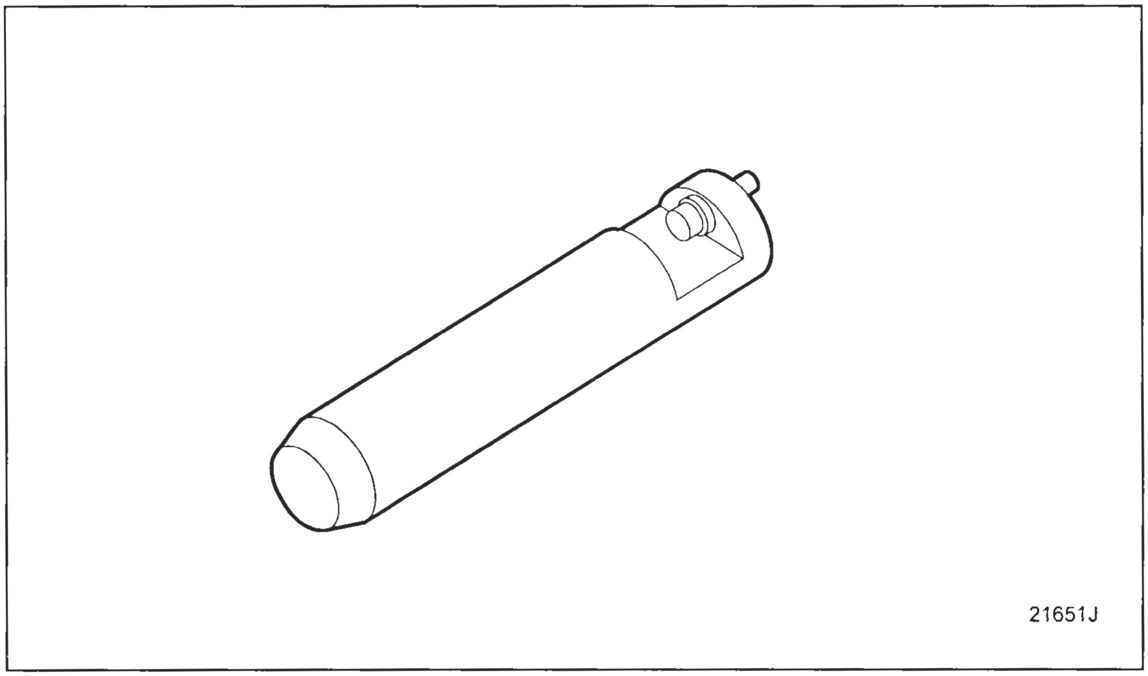


Figure 1–332 Balance Shaft Removal Tool

2. Remove the two M8 capscrews that attach the left side thrust plate to the balance support.
3. Slide the shaft out of the support, being careful to support the gear end and remainder of the shaft as it leaves the support.
4. Remove the balance shaft removal tool from the support and repeat the process for the right side shaft.

Using tool set J 39819, remove balance shaft rear bushings as follows:

1. Place bushing installer J 39819–1 and C–washer J 7593–4 onto the end of shaft 39819–5 and insert the shaft completely through the cradle from the front . See Figure 1–333.

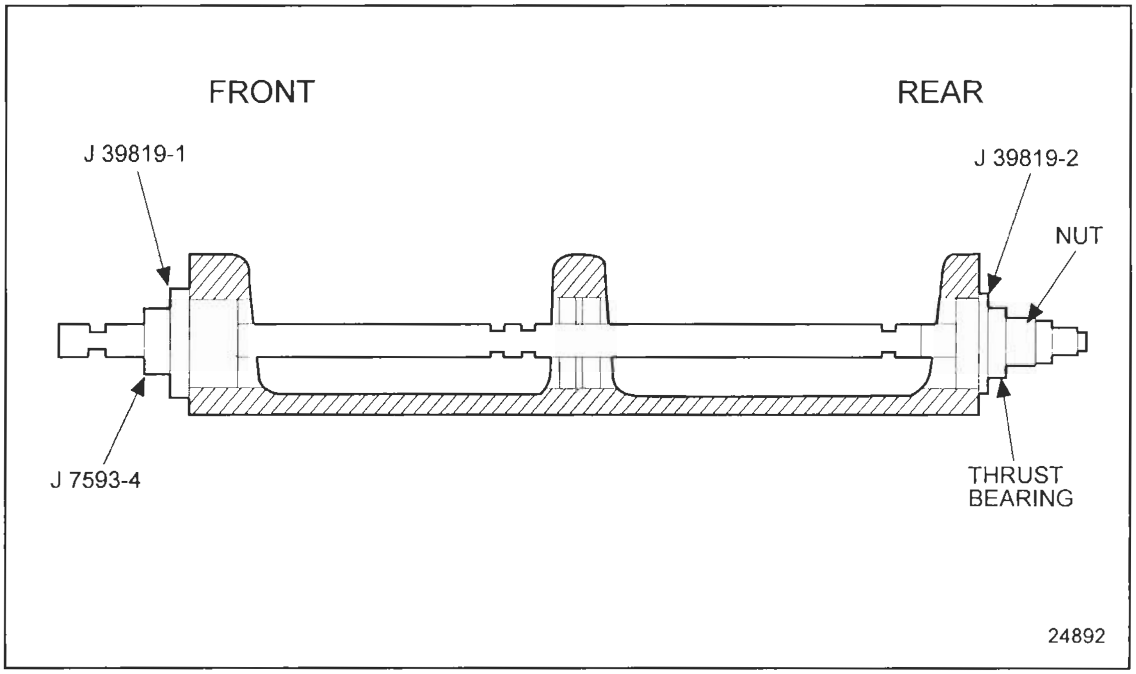


FIGURE 1–333 Remove Rear Bushings

2. Place bushing installer J 39819–2 and the thrust bearing over the threaded end of the shaft and install the 1 7/16 in hex nut.
3. Hold the shaft with a 5/8 in. wrench to keep it from turning, then tighten the hex nut until the rear bushing is removed.
4. Remove the tools and repeat this procedure to remove the remaining rear bushing.

Remove the balance shaft center bushings as follows:

1. Insert shaft J 39819–5 halfway through the front of the cradle, then place C–washer J 7593–4 and bushing installer J 39819–2 over the threaded end. Pass the shaft through the center and rear bushing bore areas. See Figure 1–334.

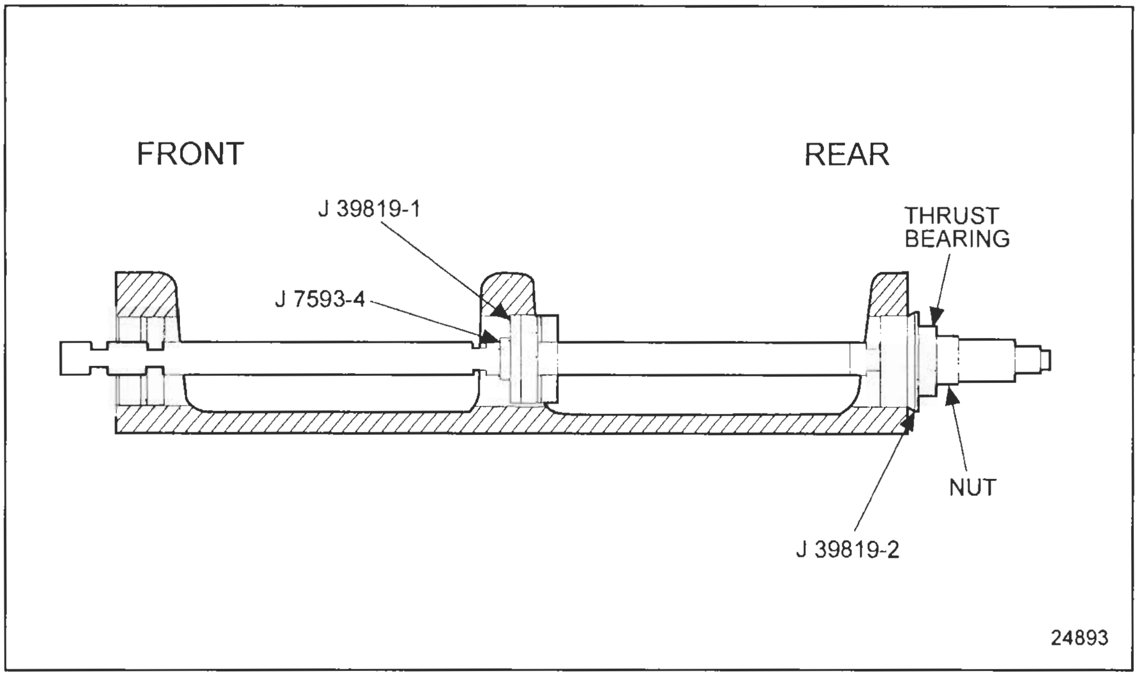


FIGURE 1–334 Remove Center Bushings

2. Place centering device J 39819–3 and the thrust bearing over the threaded end of the shaft and install the 1 7/16 in hex nut.
3. Hold the shaft with a 5/8 in. wrench to keep it from turning, then tighten the hex nut until the center bushing is removed.
4. Remove the tools and repeat this procedure to remove the remaining center bushing.

Remove balance shaft front bushings as follows:

1. Place C–washer J 7593 and bushing installer J 39819–2 onto the end of shaft J 39819–5 and insert the shaft completely through the cradle from the front. See Figure 1–335.

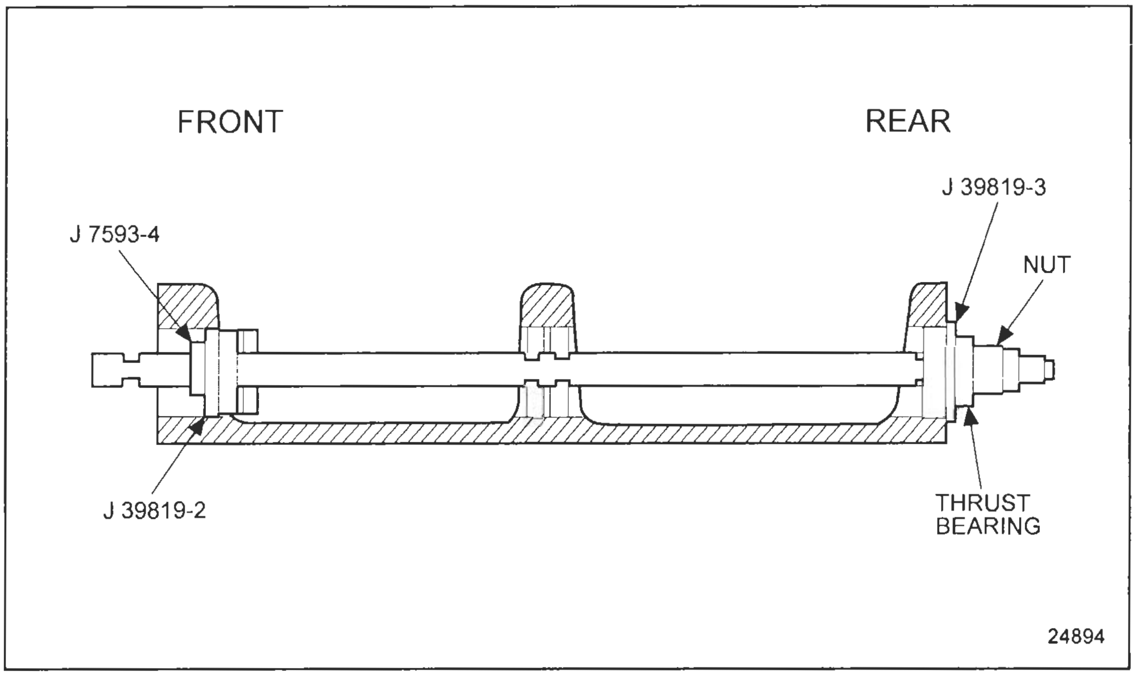


FIGURE 1–335 Remove Front Bushings

2. Place centering device J 39819–3 and the thrust bearing over the threaded end of the shaft and install the 1 7/16 in hex nut.
3. Hold the shaft with a 5/8 in. wrench to keep it from turning, then tighten the hex nut until the front bushing is removed.
4. Remove the tools and repeat this procedure to remove the remaining front bushing.

1.27.2.1 Inspection of the Balance Shaft

Inspect the balance shaft as follows:

1. Clean all removed parts in clean fuel oil.
2. Ensure all oil passages are clear.

CAUTION:
To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

3. Dry components with compressed air.
4. Inspect balance shaft contact surfaces for scoring, replace if excessively scored.
5. Inspect balance shaft bearings for scoring, pitting, flaking, etching, or signs of overheating. If any of these are evident the bearing must be replaced.
6. Inspect balance shaft support for cracks, signs of overheating, or other damage. Replace as necessary.

1.27.3 Installation of the Balance Shaft

Install balance shaft rear bushings as follows:

1. Place bushing installer J 39819–1 and C–washer J 7593–4 onto the end of shaft 39819–5 and insert the shaft completely through the cradle from the front . See Figure 1–336.

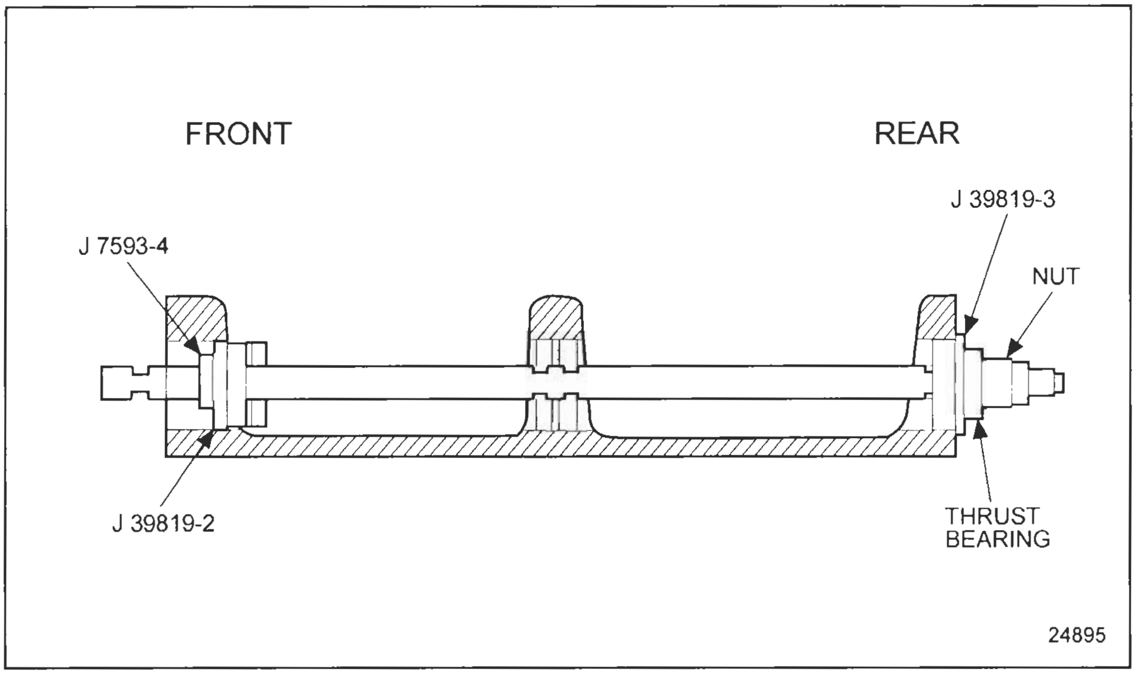


FIGURE 1–336 Install Rear Bushings

2. Place a new bushing on bushing installer J 39819–2 and install over the threaded end of the shaft. Place the thrust bearing on the shaft and install the 1 7/16 in hex nut.
3. Hold the shaft with a 5/8 in. wrench to keep it from turning, then tighten the hex nut until the rear bushing is installed.
4. Remove the tools and repeat this procedure to install the the remaining rear bushing.

Install the balance shaft center bushings as follows:

1. Place bushing installer J 39819–1 and C–washer J 7593–4 onto the end of shaft 39819–5 and insert the shaft half way through the cradle from the front. See Figure 1–337.

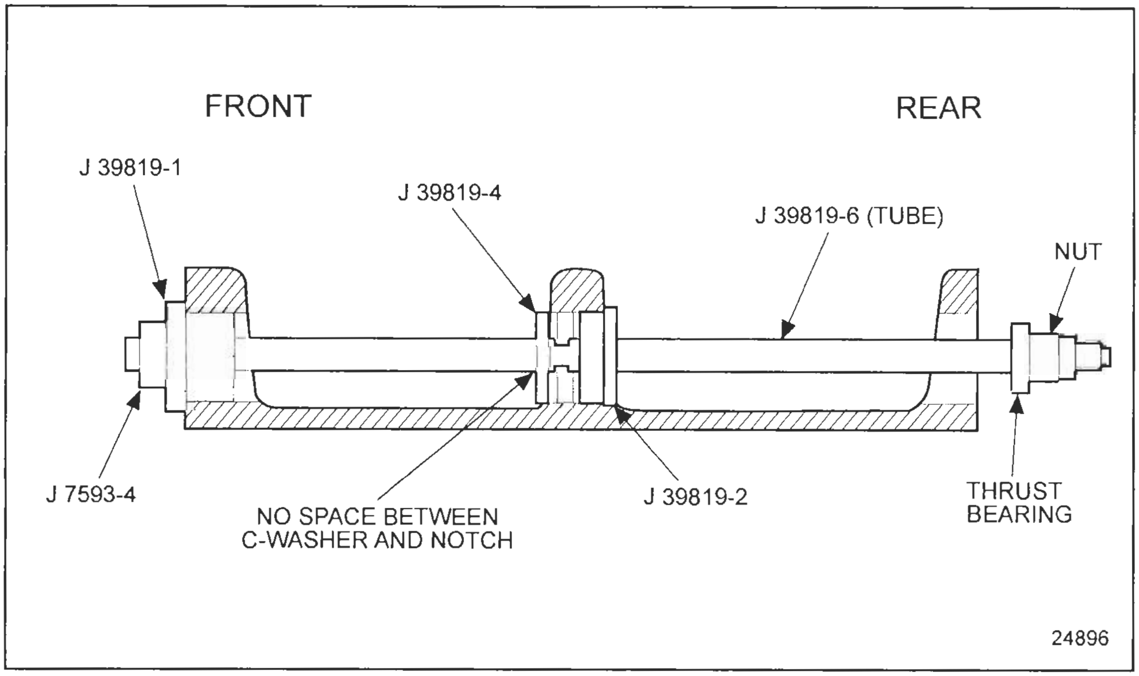


FIGURE 1–337 Install Center Bushings

2. Install C–washer J 39819–4 onto the shaft and pass the shaft through center bearing bore.
3. Position a new bushing on installer J 39819–2, install onto the shaft, and pass the shaft completely through the rear bore. The bushing is located properly when the J 39819–4 C–washer is tight against the back of the notch in the shaft
4. Slip tube J 39819–6 over the shaft, then install the thrust bearing and nut onto the threaded end of the shaft.

NOTICE:
Before installing the bushing, align the hole in the bushing with the oil supply hole in the bearing bore. Failure to observe this step will result in inadequate flow of lube oil to the bearing, which may lead to bearing and shaft damage.

5. Hold the shaft with a 5/8 in. wrench to keep it from turning, then tighten the hex nut until the center bushing is installed.
6. Remove the tools and repeat this procedure to install the remaining center bushing.

Install the balance shaft front bushings as follows:

1. Place C–washer J 7593 and bushing installer J 39819–1 onto the end of shaft J 39819–5 and position a new bushing on the installer. Insert the shaft completely through the cradle from the front. See Figure 1–338.

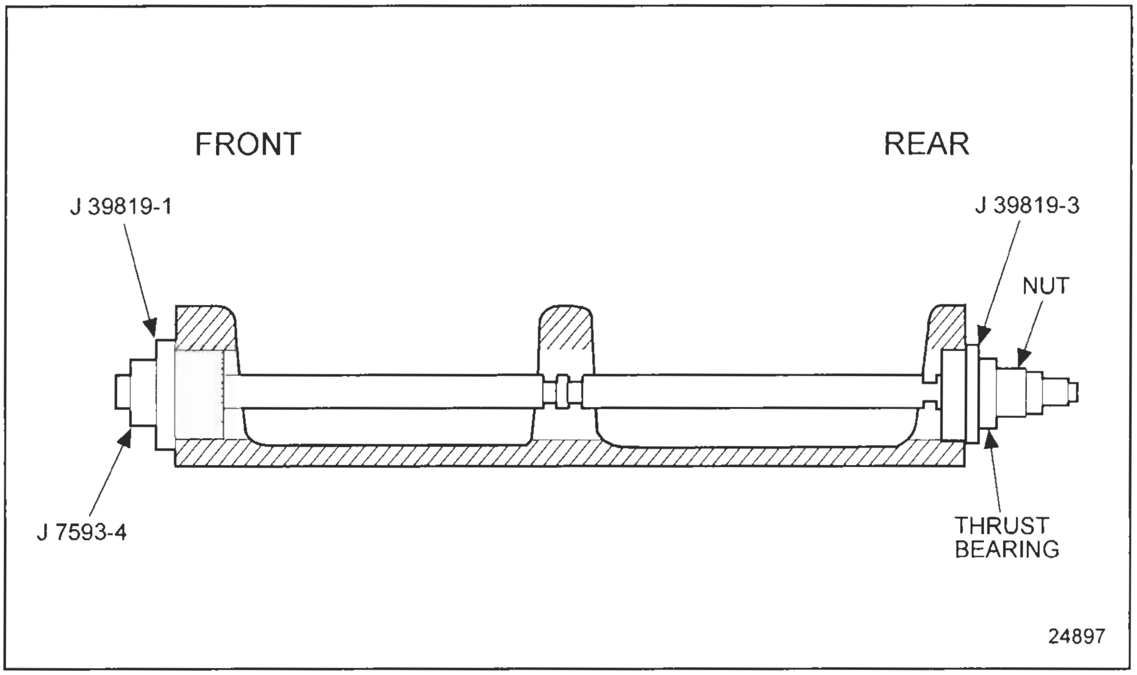


FIGURE 1–338 Install Front Bushings

2. Place centering device J 39819–3 and the thrust bearing over the threaded end of the shaft and install the 1 7/16 in hex nut.
3. Hold the shaft with a 5/8 in. wrench to keep it from turning, then tighten the hex nut until the front bushing is installed.
4. Remove the tools and repeat this procedure to install the remaining front bushing.

Install the balance shaft and assembly as follows:

1. Attach the balance shaft installation service tool, J 39817, to the right side shaft.
2. Lubricate the bushing in the support and the shaft journals with clean engine oil.
3. With balance shaft weights on top and supporting the gear end of the shaft assembly, slide the installation tool and shaft into the support.
4. To allow clearance for assembly of the oil pump, loosely install the two M8 capscrews that fasten the thrust plate to the support.
5. Repeat the previous steps for the left side shaft.
6. Proper timing of the balance mechanism is essential to proper engine operation. Using the oil pump gear holding tool J 39816, the balance shafts can be aligned and held in the position necessary to attain proper timing. See Figure 1–328.

NOTE:
The counterweighted balance shafts will naturally want to rotate back into position unless held in place.

7. Before installation of the oil pump, rotate the drive gear so that the timing marks match the locating of those on the balance shaft gears. See Figure 1–339.

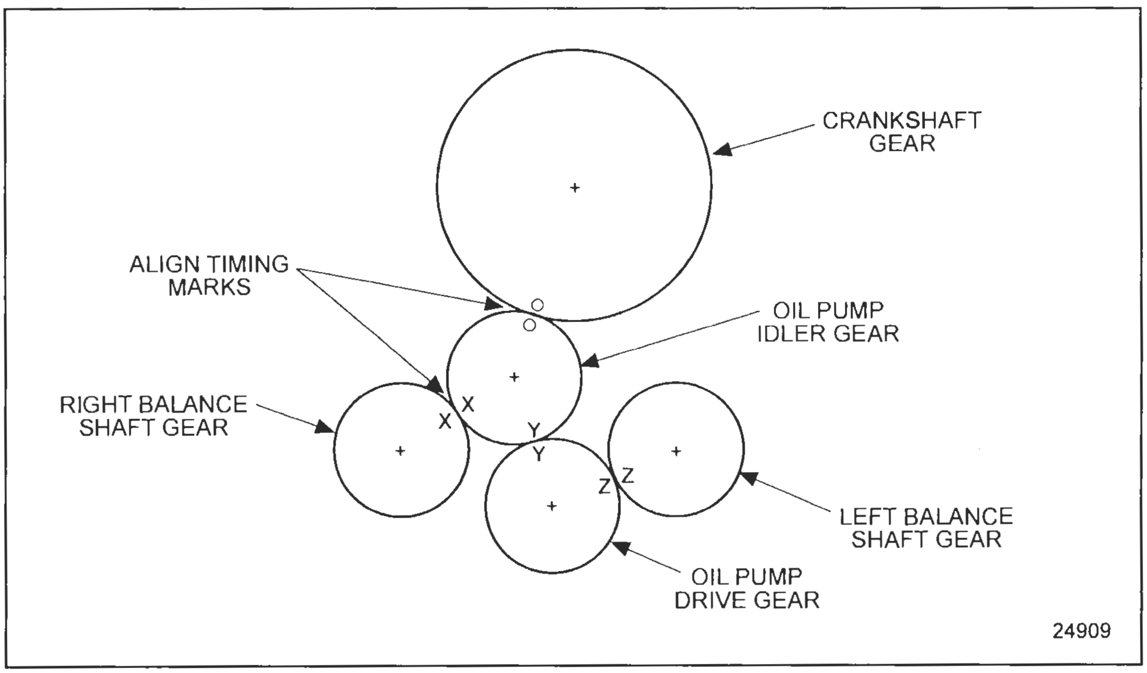


Figure 1–339 Balance Shaft Drive Gear Timing

Install the oil pump as follows:

1. Install the oil pump, taking care to match each of the letters stamped on the pump idler gear and pump drive gear with the same letter of the left and right side balance shafts.
2. When sure that all of the gears are properly aligned, tighten the M8 capscrews in each of the thrust plates, torque 34 N·m (25 ft·lb).

NOTE:
Bolts are installed from back side of pump.

3. Install and tighten the four M8 capscrews that attach the oil pump to the balance support torque 34 N·m (25 ft·lb). See Figure 1–340.

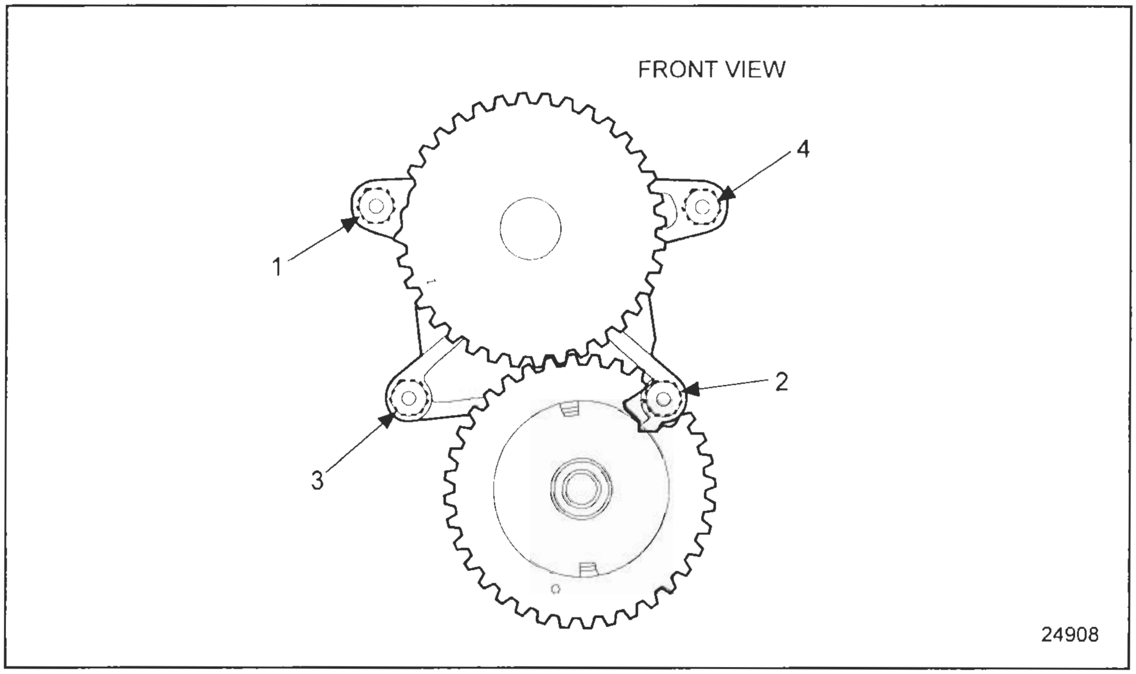


Figure 1–340 Oil Pump Torque Sequence

4. To aid balancer timing, leave the oil pump gear holding tool, J 39816, in place until the balance assembly is installed in the engine.
5. Install new O-ring seals on both ends of the oil pump outlet tube and lubricate them with clean engine oil.
6. Loosely assemble the left and right side oil inlet tube brackets to the inlet tube using the M10 nuts and bolts.
7. Install one end of the oil pump outlet tube into the inlet tee, the other into the pump body.

8. Install the inlet tee and attach the relief valve using two M8 capscrews torque 34 N·m (25 ft·lb).
9. Install the regulator valve using two M8 capscrews torque 34 N·m (25 ft·lb).
10. Install the two M10 capscrews that attach the left and right side oil inlet tube brackets to the support torque 48 N·m (35 ft·lb).
11. Tighten the M10 nuts and bolts that fasten the tube bracket to the inlet tube.
12. Attach the balancer assembly to the lifting jack service tool, J 39814–A.
13. Use guide studs in opposite center holes to properly align the balance shaft support.
14. Before the balance assembly is fastened to the cylinder block, make sure again that the timing marks on the balance gears are aligned with the oil pump idler and drive gears and that cylinder No. 1 at top dead center (on either the compression or exhaust stroke). With cylinder No. 1 at top dead center and all gear meshes properly aligned, the counter weights for both balance shafts should be in the bottom most, or 6 o'clock, position.
15. Raise the balance assembly to the cylinder block and attach it using the nine M12 capscrews torque 115 N·m (85 ft·lb).
16. Remove guide studs and stall remaining two bolts, torque to 115 N·m (85 ft·lb).
17. Remove the oil pump gear holding tool, J 39816, from the balance shafts.
18. Install the oil pan.

1.27.4 Installing a Balance Shaft and Oil Pump Mechanism (Which Has Not Been Disassembled)

If the balance shaft and oil pump mechanism is removed from the Series 50 engine and is not disassembled, it can be reinstalled on the engine and correctly timed without further disassembly of engine components. The procedure outlined below permits reinstallation of this mechanism with a minimum of engine downtime. Only this procedure should be used when replacing a balance shaft and oil pump mechanism which has not been disassembled.

To reinstall a balance shaft and oil pump mechanism which has not been disassembled, proceed as follows:

1. Remove two M8 bolts in each balance shaft thrust plate and slide the shafts forward, disengaging them from the lube oil pump/idler gear assembly.
2. Spin the pump/idler gears until the "Y" letters line up. See Figure 1-341. This may require up to 20 turns.

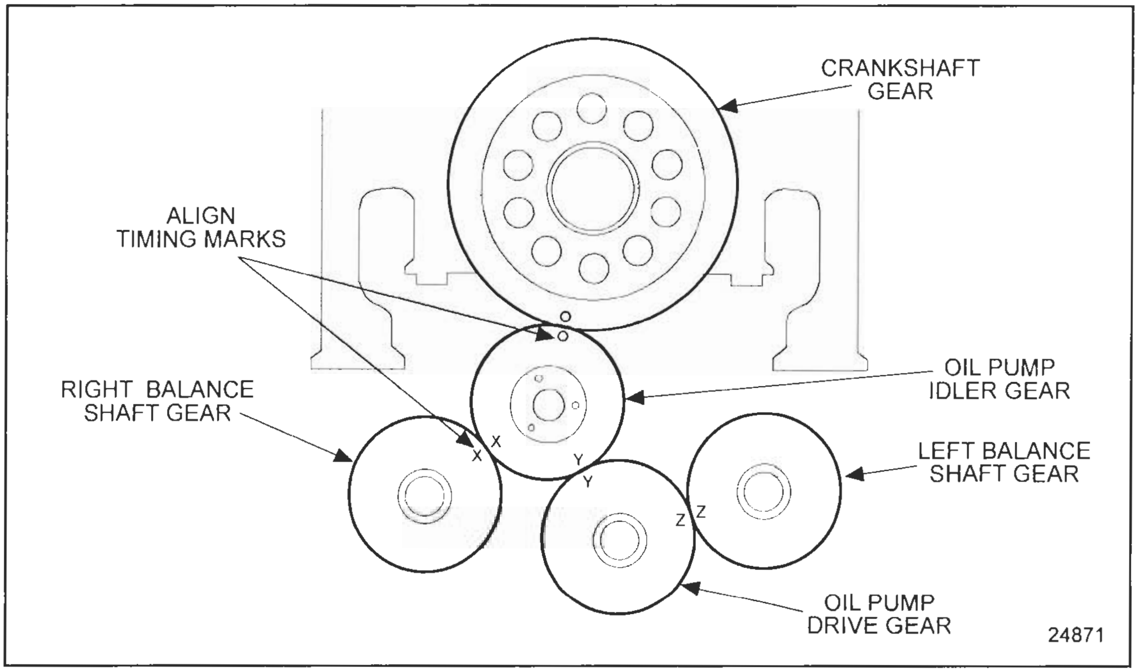


FIGURE 1–341 Balance Shaft Drive Gear Timing

3. With the "Y's" lined up on the pump gear and idler gear, install the left and right balance shafts with the timing marks lined up as shown. See Figure 1-341.

4. Lock the mechanism in this position with oil pump gear holding tool J 39816. See Figure 1-342

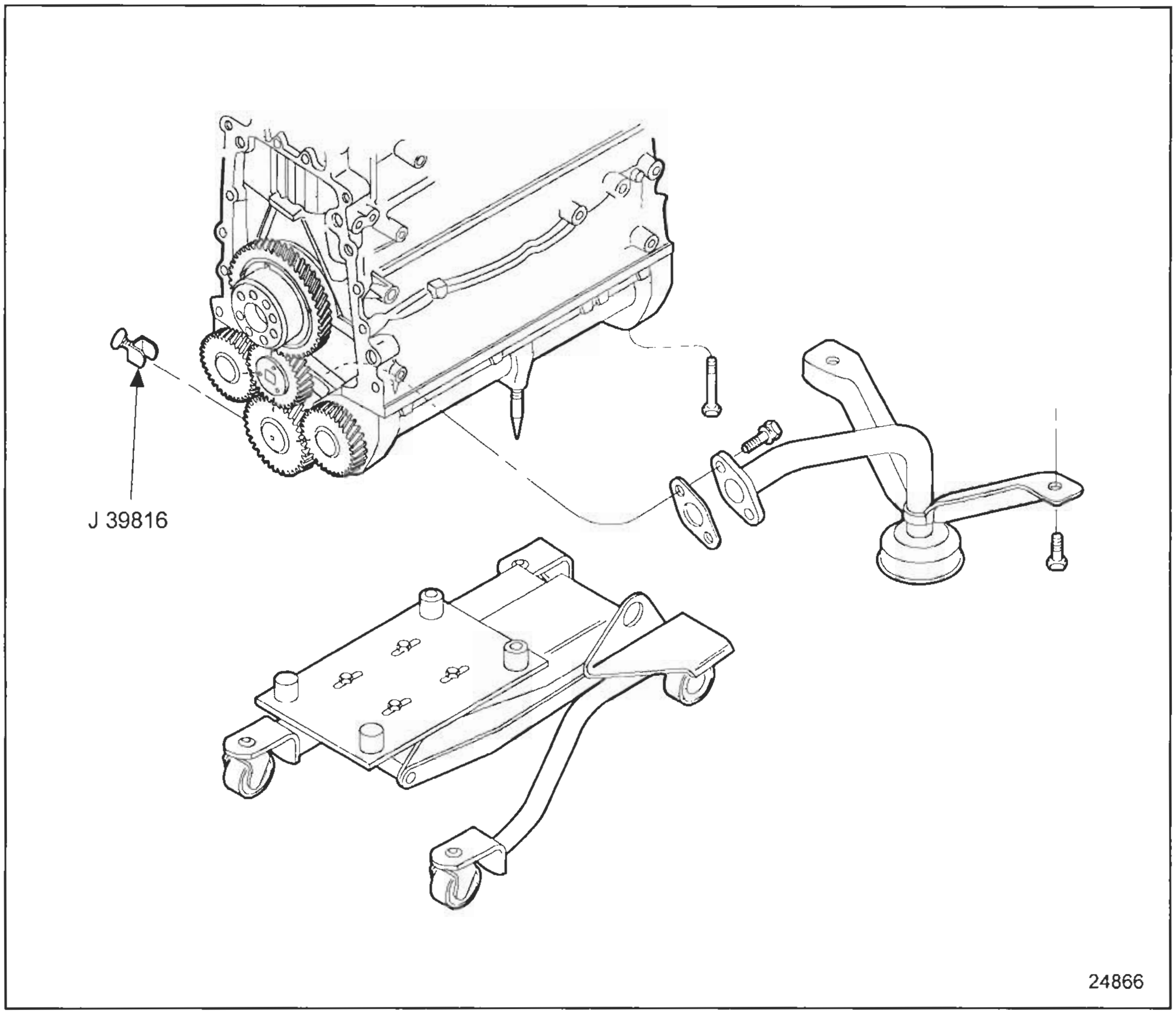


FIGURE 1-342 Balance Shaft and Oil Pump Mechanism Showing Tool J 39816

5. Reinstall the two M8 bolts in each balance shaft thrust plate and tighten to 30 - 38 N·m (22 - 28 lb·ft) torque. Recheck position of timing marks and realign, if required

6. Bar the engine until the "O" on the crankshaft gear is in the *down* position.

NOTICE:
Failure to establish piston top dead center or to properly align timing marks on balance shaft and idler gears or to line up the "O" marks on the crank gear and oil pump idler gear before reinstalling the balance shaft and oil pump mechanism will result in an out–of–time condition. This will cause engine vibration, which may lead to serious engine damage after start–up.

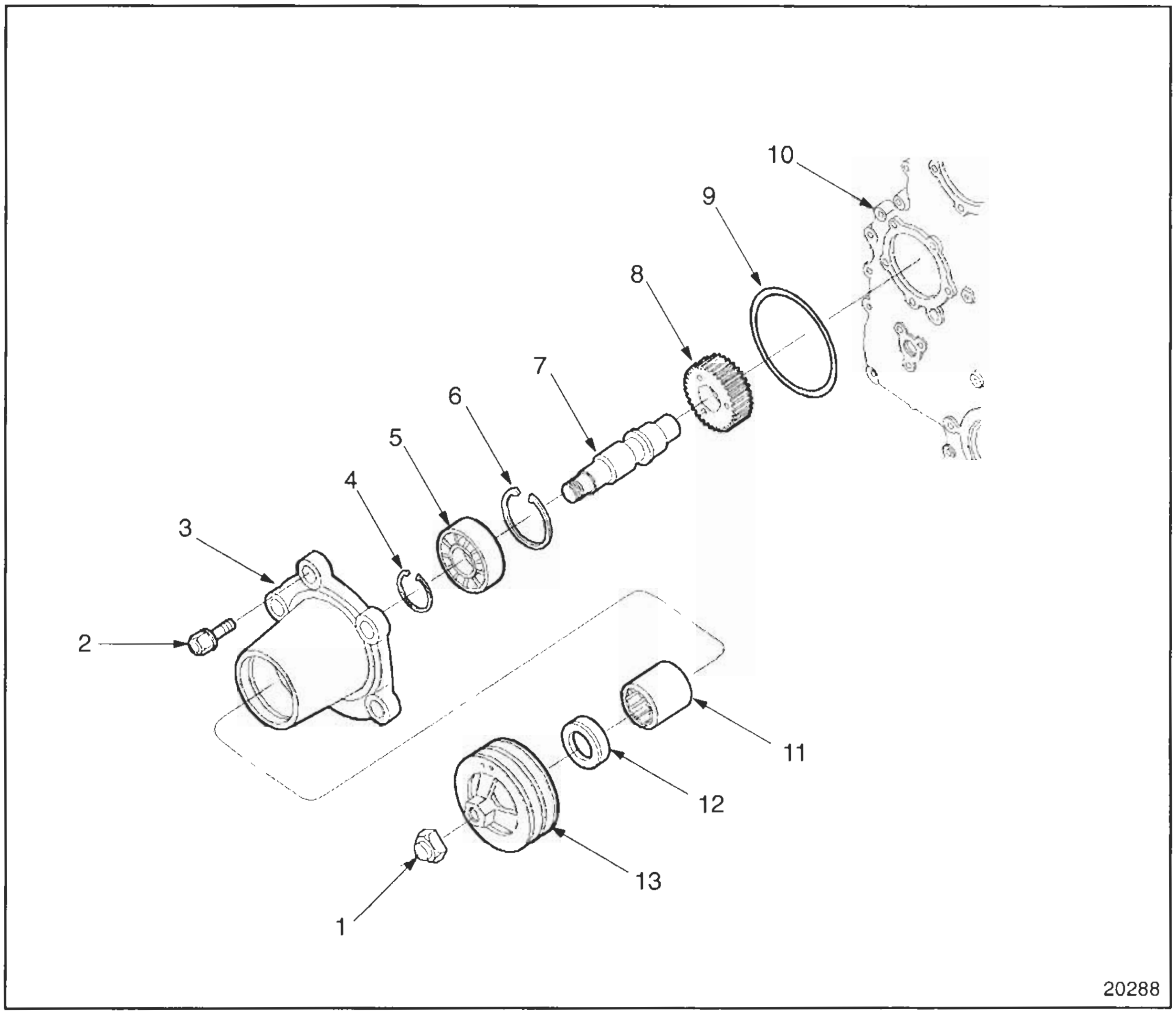
7. Attach the mechanism to lifting jack service tool J 39814. Make sure guide studs are installed in opposite center holes to properly align the mechanism support.
8. Using a transmission jack, carefully raise the mechanism to the cylinder block, lining up the "O" marks on the crank gear and oil pump idler gear. See Figure 1–342.
9. Secure the mechanism to the block with the nine M12 cap screws previously removed. Tighten screws to 115 N·m (85 lb·ft) torque.
10. Remove the guide studs from the mechanism and reinstall the two remaining M12 cap screws. Tighten to 115 N·m (85 lb·ft) torque.
11. Using the two M8 capscrews removed, attach the suction tube flange to the oil pump body.
12. Remove oil pump gear holding tool J 39816.
13. Using the two M10 capscrews previously removed, fasten the oil suction tube brackets to the balance support.

NOTICE:
Failure to remove the oil pump gear holding tool before installing the oil pan may result in severe gear train damage at engine startup.

14. Install the oil pan.

1.28 ACCESSORY DRIVE

The accessory drive assembly is mounted to the front of the gear case cover and utilizes a two-groove pulley to drive the alternator. See Figure 1-343.



1. Locknut
2. Mounting Bolts (5)
3. Drive Housing
4. Snap Ring (Small)
5. Ball Bearing
6. Snap Ring (Large)
7. Driveshaft
8. Drive Gear
9. O-ring
10. Gear Case Cover
11. Needle Bearing
12. Oil Seal
13. Pulley

Figure 1-343 Accessory Drive Assembly Related Parts

The accessory drive assembly is splash fed oil through two holes in the casting of the accessory drive housing. The oil returns to the crankcase via the gear case.

The accessory drive is driven by a drive gear which is pressed onto the driveshaft. The drive gear meshes with the bull gear and is driven at 2.41 times engine speed.

The driveshaft is supported by a ball bearing at the drive end and a needle bearing at the pulley end.

NOTE:
A design change has been made to the accessory drive assembly. The needle bearing inner race is now incorporated into the driveshaft. See Figure 1–343.

An O–ring is used to seal the accessory drive housing to the gear case cover.

1.28.1 Repair and Replacement of the Accessory Drive

To determine if repair is possible or replacement is necessary, perform the following procedures. See Figure 1–344.

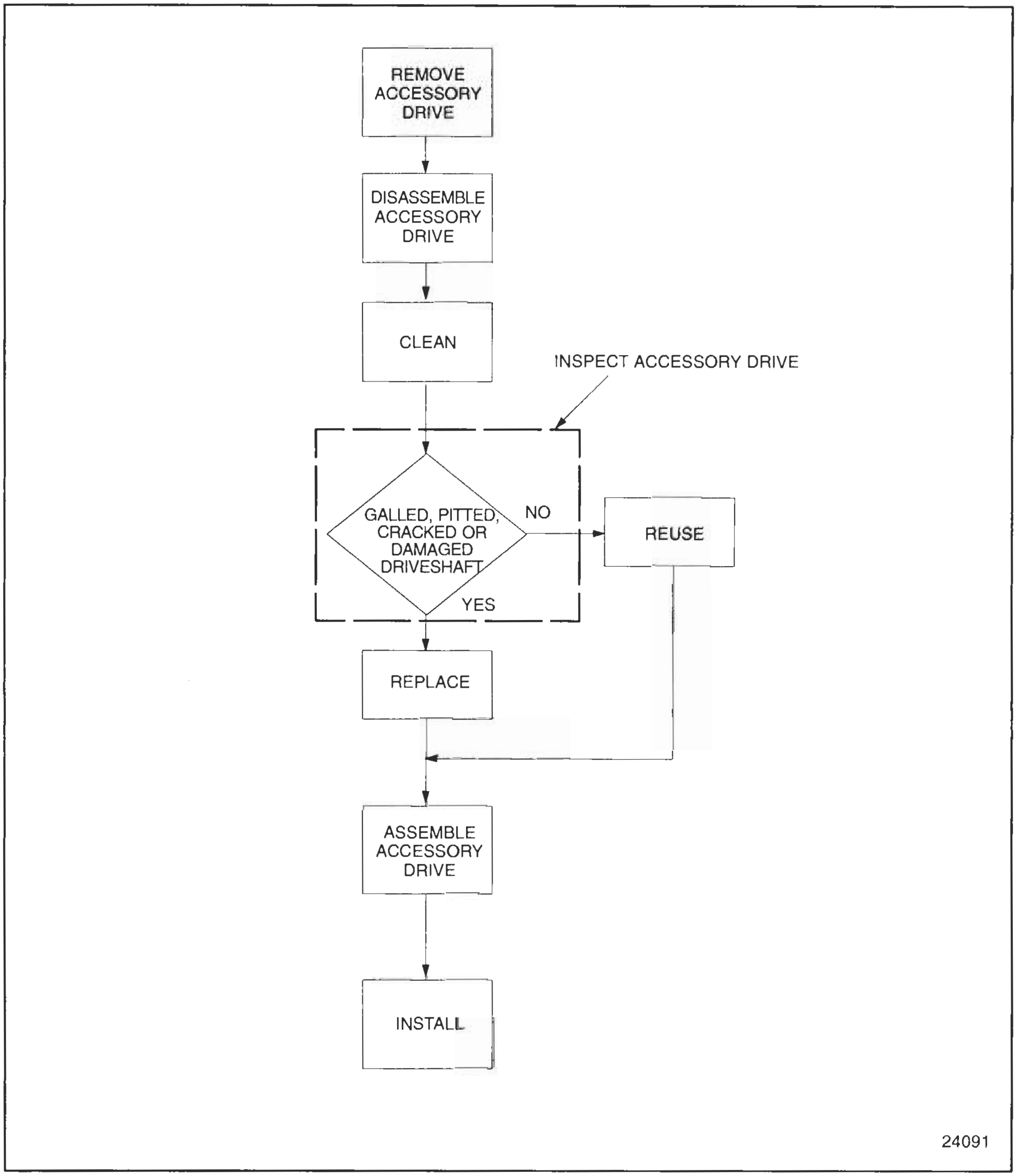


Figure 1–344 Flowchart for Repair or Replacement of Accessory Drive

1.28.2 Cleaning and Removal of the Accessory Drive

Precleaning is not necessary.

Remove the accessory drive as follows:

1. Loosen the alternator mounting bolts and the adjusting rod nuts to get slack in the alternator drive belts. Remove the alternator drive belts. See Figure 1-345.

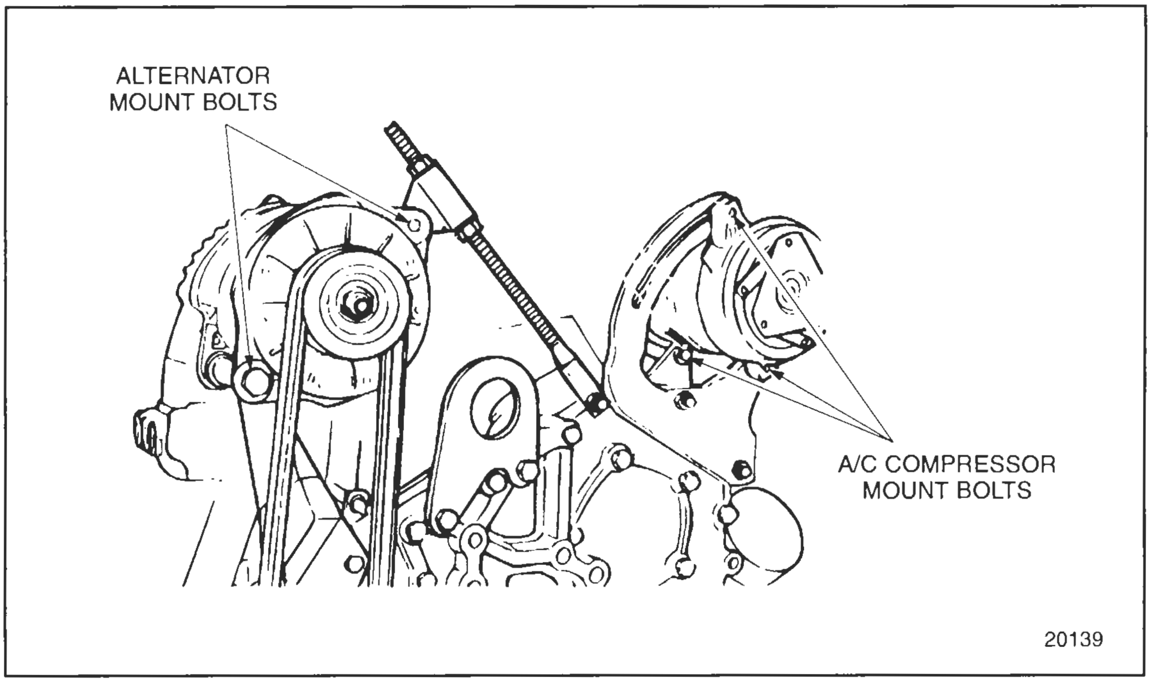


Figure 1–345 Alternator Mount Bolts

2. Loosen and remove the five bolts that secure the accessory drive assembly to the gear case cover.

3. Remove the accessory drive assembly by pulling it straight out of the gear case cover to avoid damaging the rubber O–ring. See Figure 1–346.

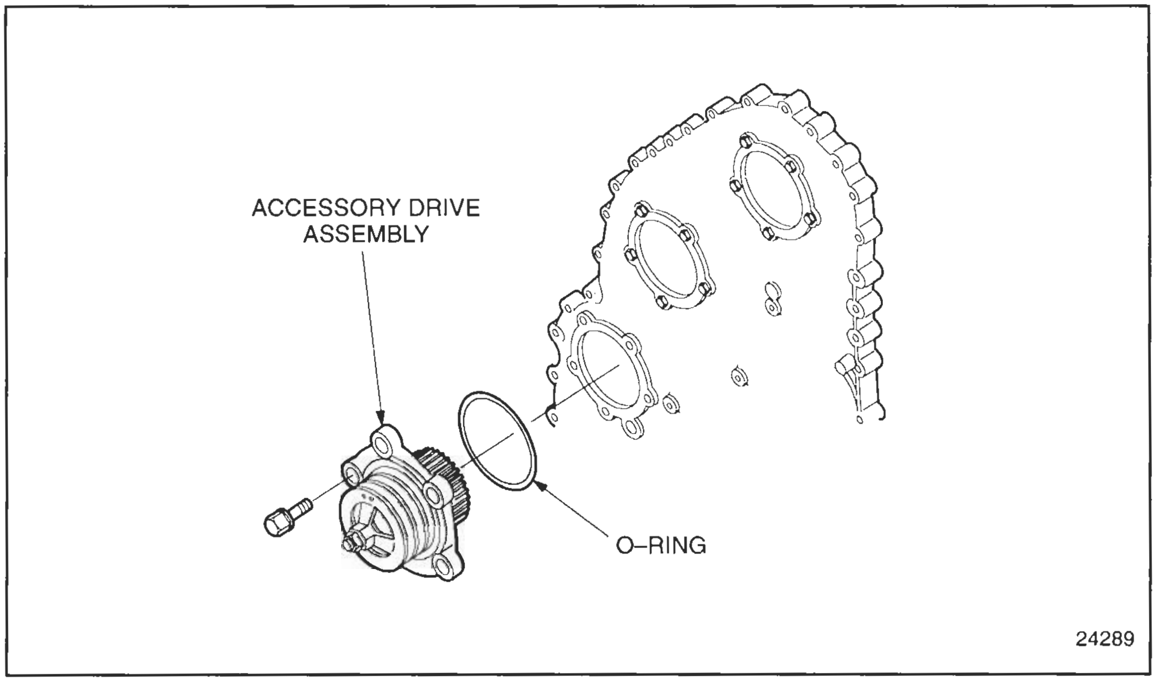


Figure 1–346 Accessory Drive Assembly Removal

1.28.3 Disassembly of the Accessory Drive

Disassemble the accessory drive as follows:

NOTE:
Use accessory drive service tool set, J 36024–C, for disassembly and assembly. See Figure 1–347.

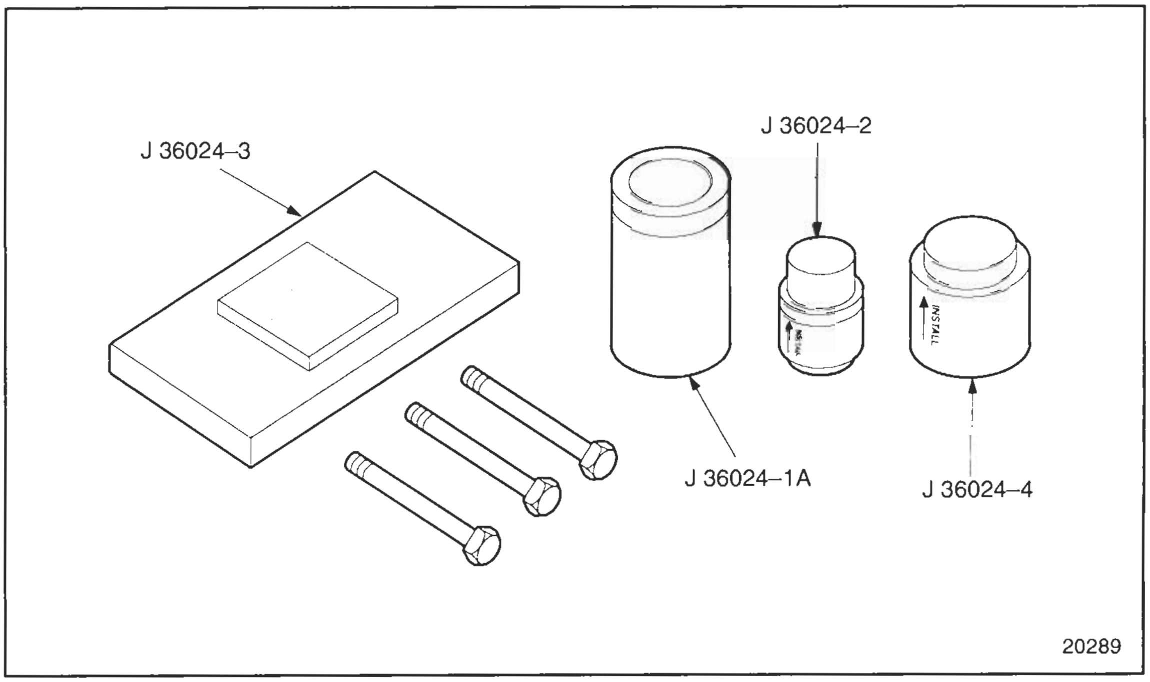


Figure 1–347 Accessory Drive Service Tool Set

1. Attach the accessory drive gear to the holding fixture, J 36024-3, using the three bolts provided. See Figure 1-348.

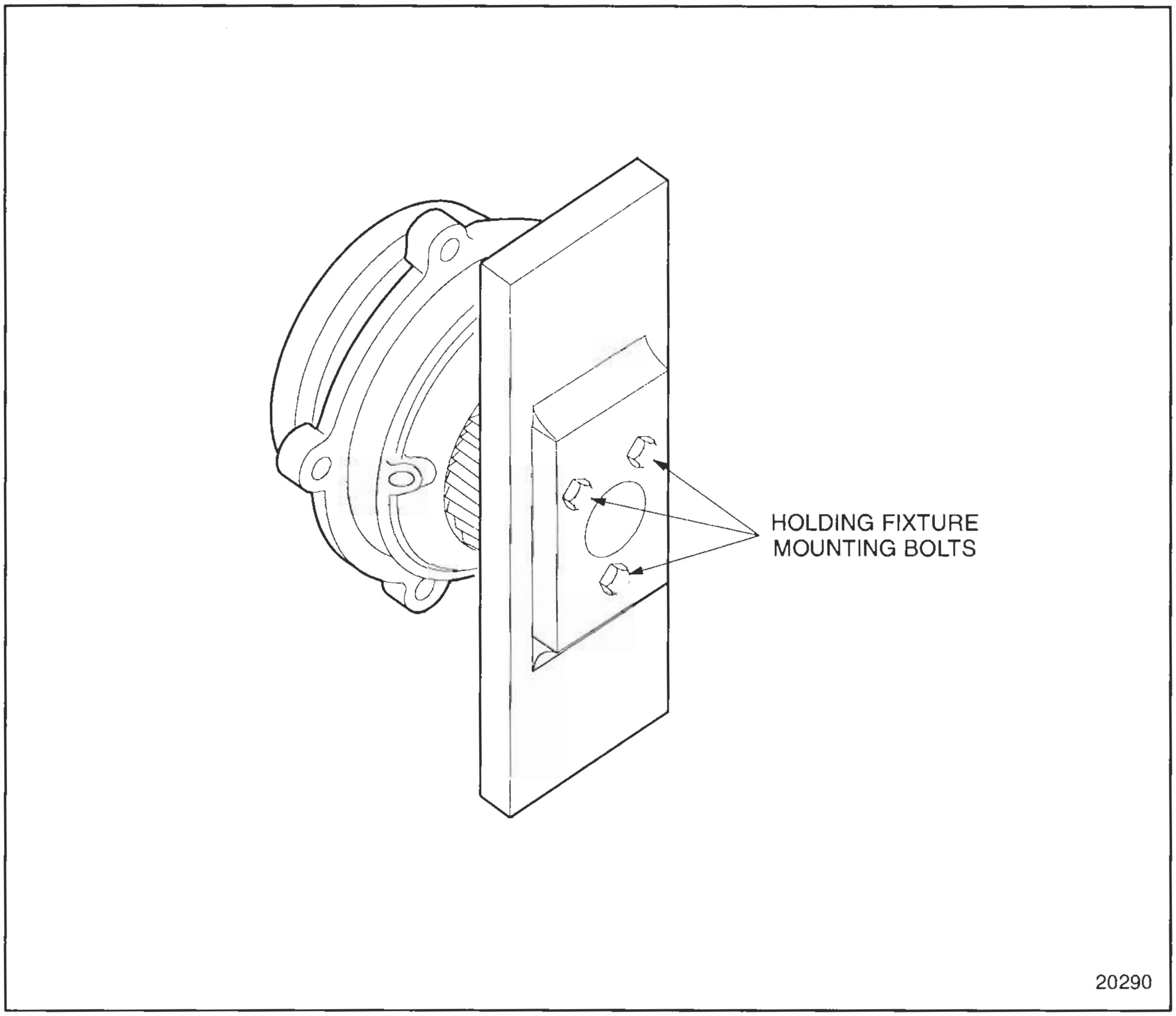


Figure 1–348 Holding Fixture

2. Place the accessory drive assembly holding fixture into a vise. See Figure 1–349.

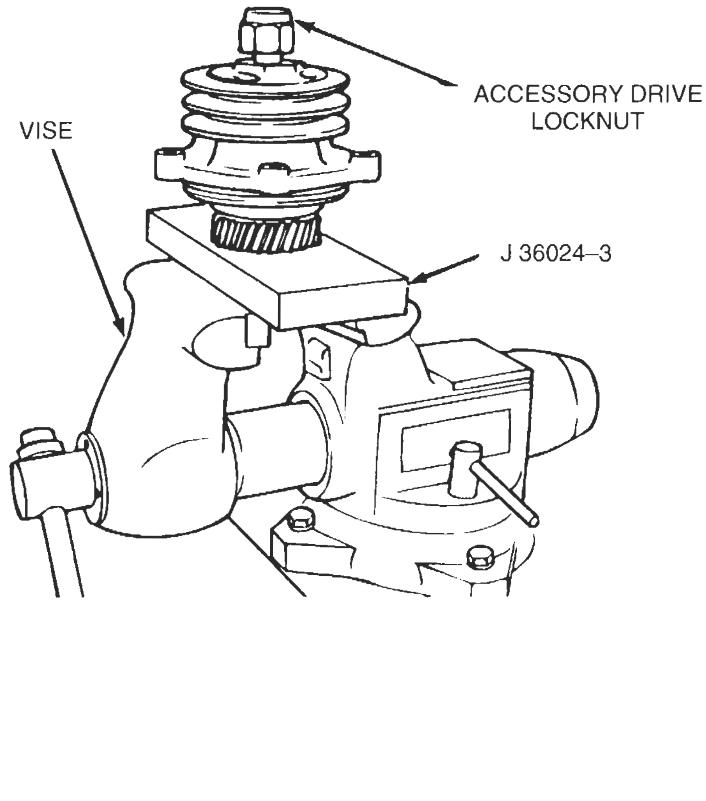


Figure 1–349 Accessory Drive Pulley Locknut Removal

3. Loosen and remove the accessory drive pulley locknut.
4. Remove the accessory drive pulley by tapping it with a rubber hammer or fiber mallet. If the pulley does not come off easily, use a puller to remove it. See Figure 1–349.

5. Position the accessory drive assembly on a press bed with the holding fixture supported. See Figure 1–350.

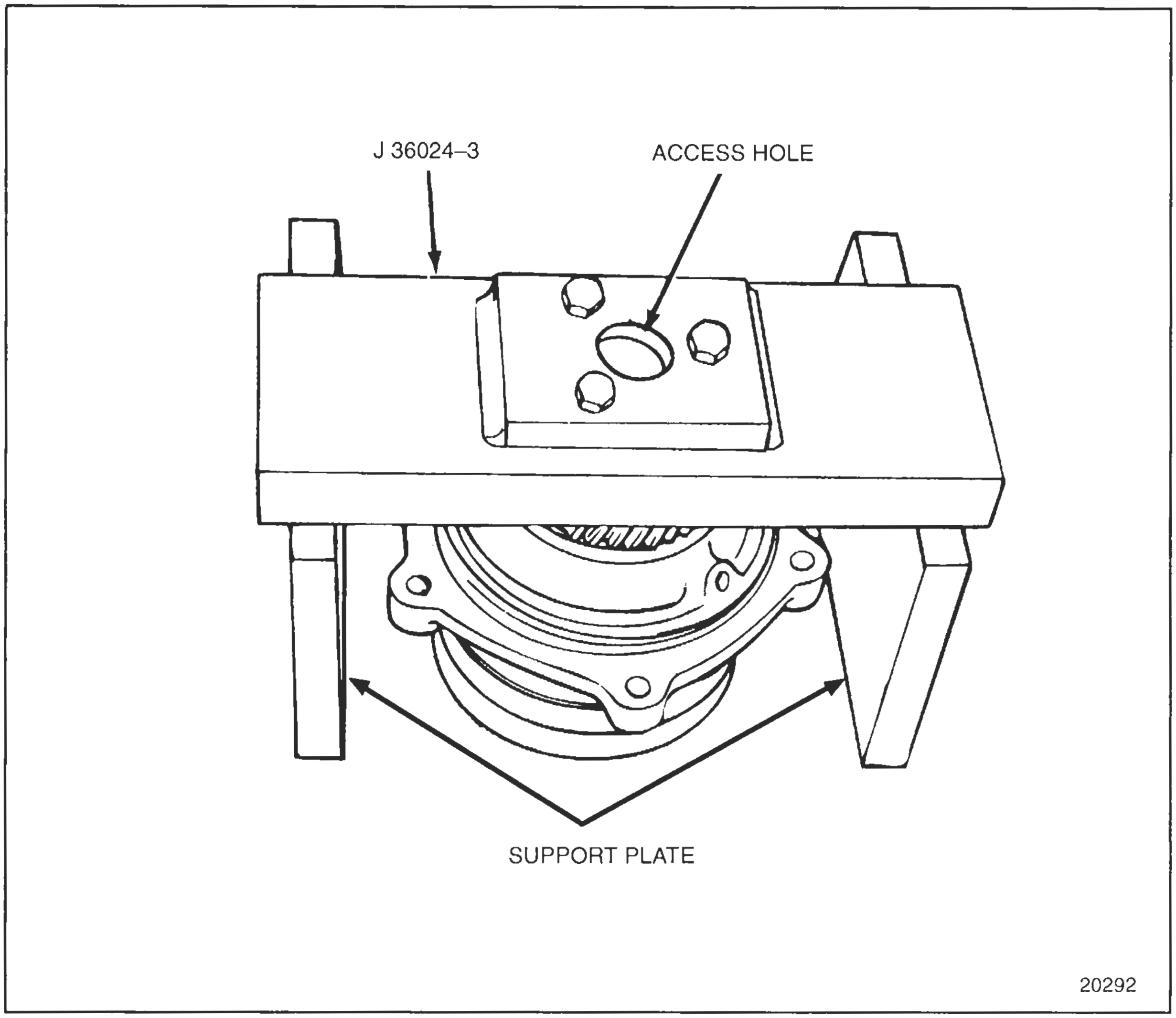


Figure 1–350 Accessory Drive Gear Removal

6. Using a press, apply pressure through the access hole in the holding fixture, J 36024–3, and press the driveshaft out of the gear.

7. Remove the snap ring from the accessory drive housing. See Figure 1-351.

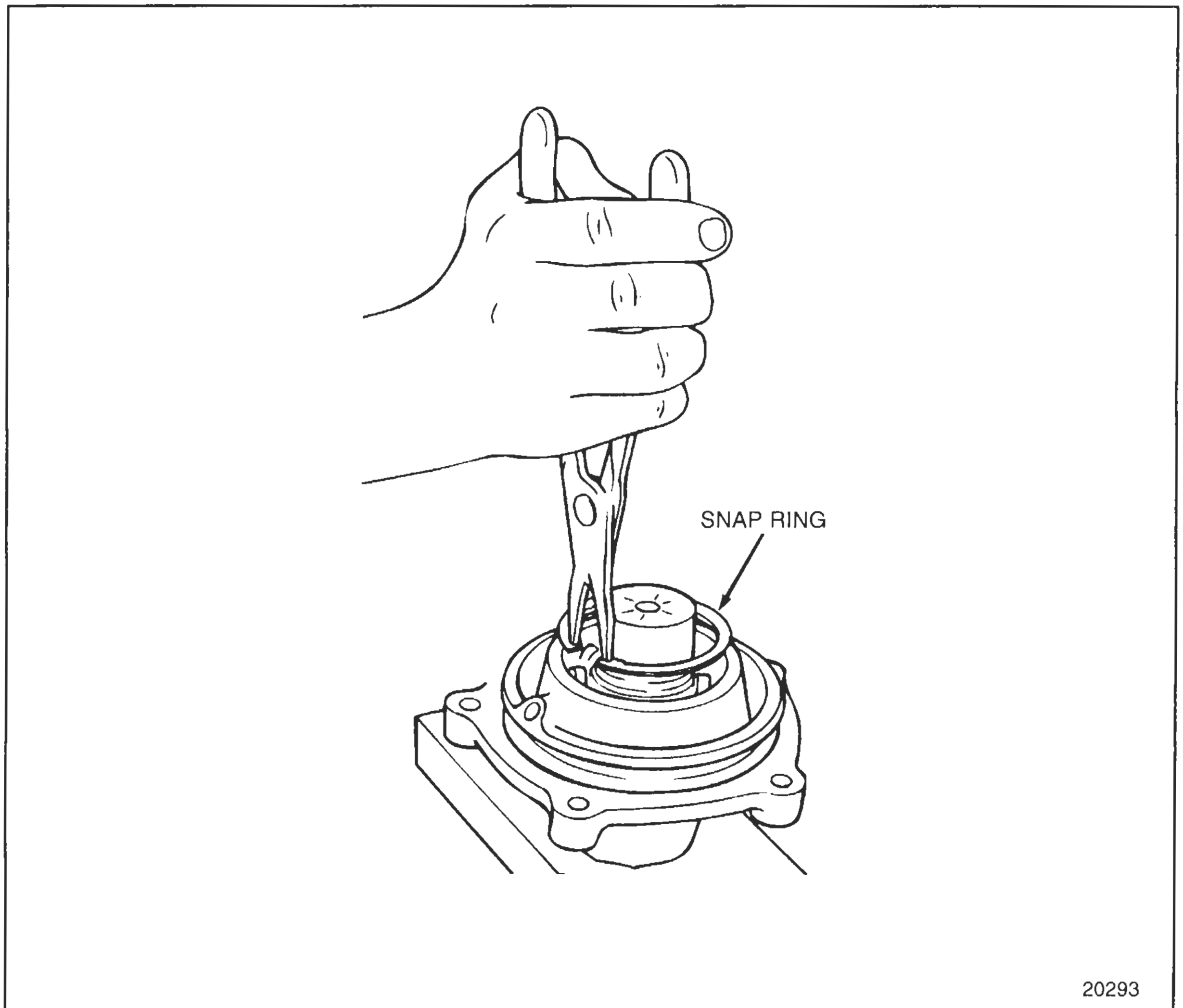


Figure 1–351 Snap Ring Removal

8. Turn the housing over and support the accessory drive housing on the machined surface using Vee-blocks.
9. Using a press, apply pressure to the pulley end of the shaft and remove the shaft and bearing assembly.
10. Turn the accessory drive housing over, and support it on the attaching bolt bosses using Vee-blocks.

NOTICE:
For assemblies with inner race for needle bearing, place the accessory driveshaft in a vise with soft jaws taking care not to damage the shaft surface.

11. Install needle bearing remover and installer, J 36024-2. See Figure 1-352. Apply pressure to J 36024-2, and remove the needle bearing.

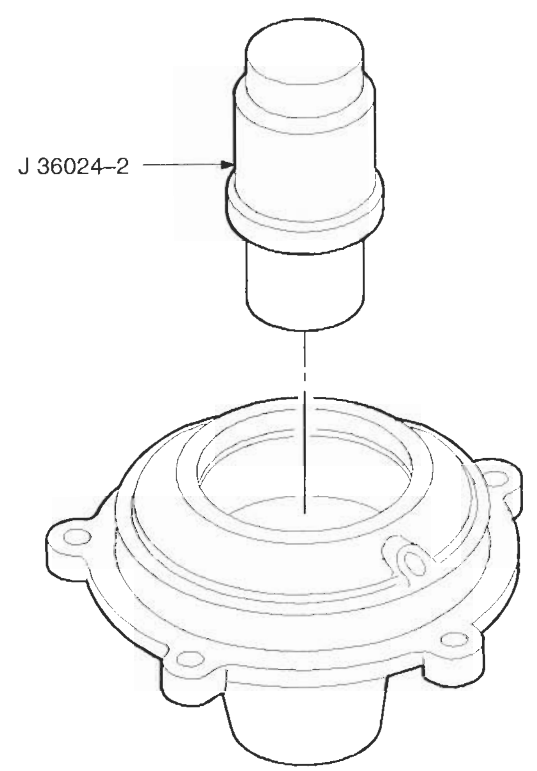


Figure 1-352 Needle Bearing Removal

12. Apply pressure to J 36024-2 and remove the needle bearing.

13. Remove the snap ring from the accessory driveshaft. See Figure 1-353.

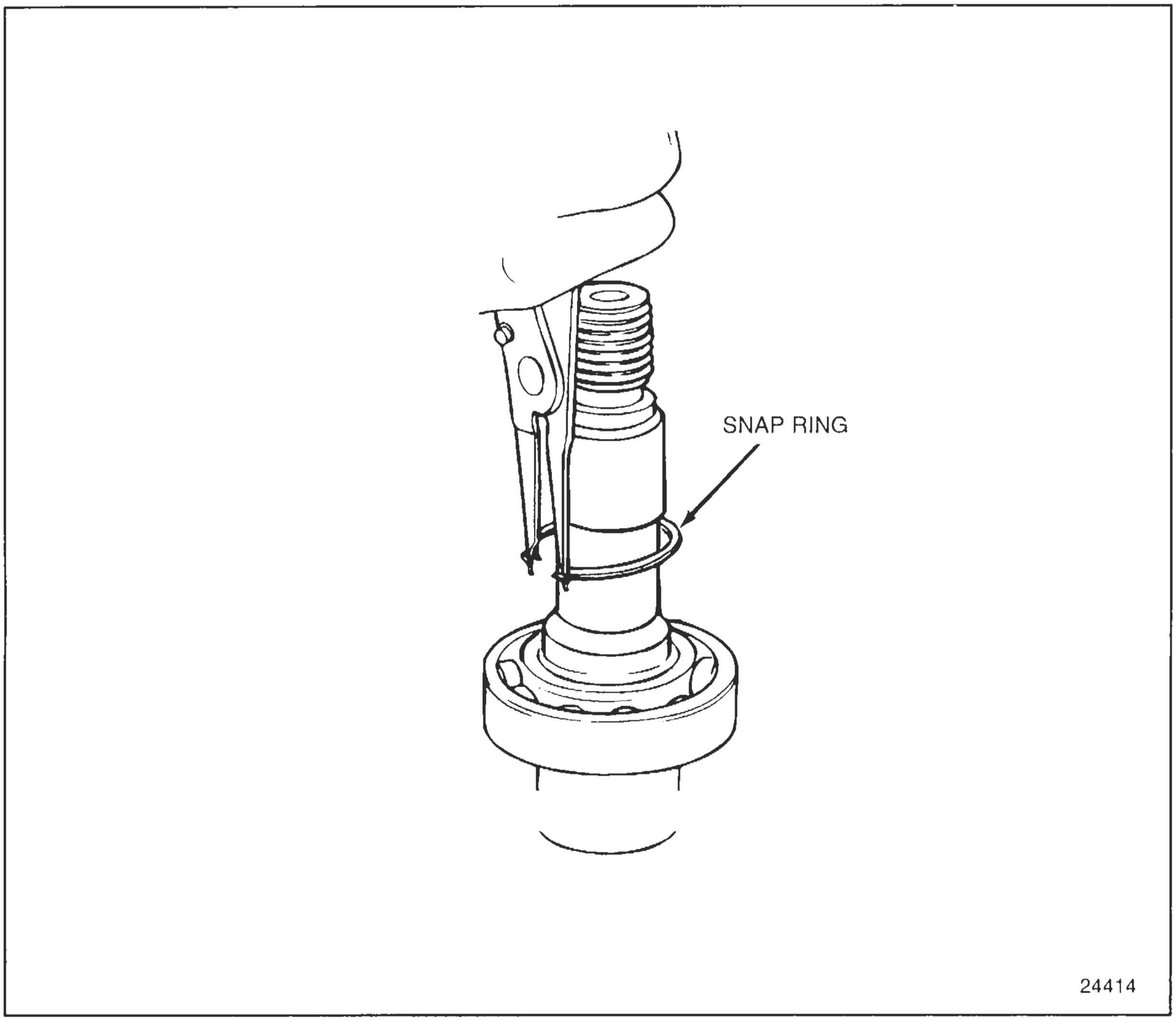


Figure 1–353 Snap Ring Removal

14. Position two steel press plates under the ball bearing outer race. See Figure 1–354.

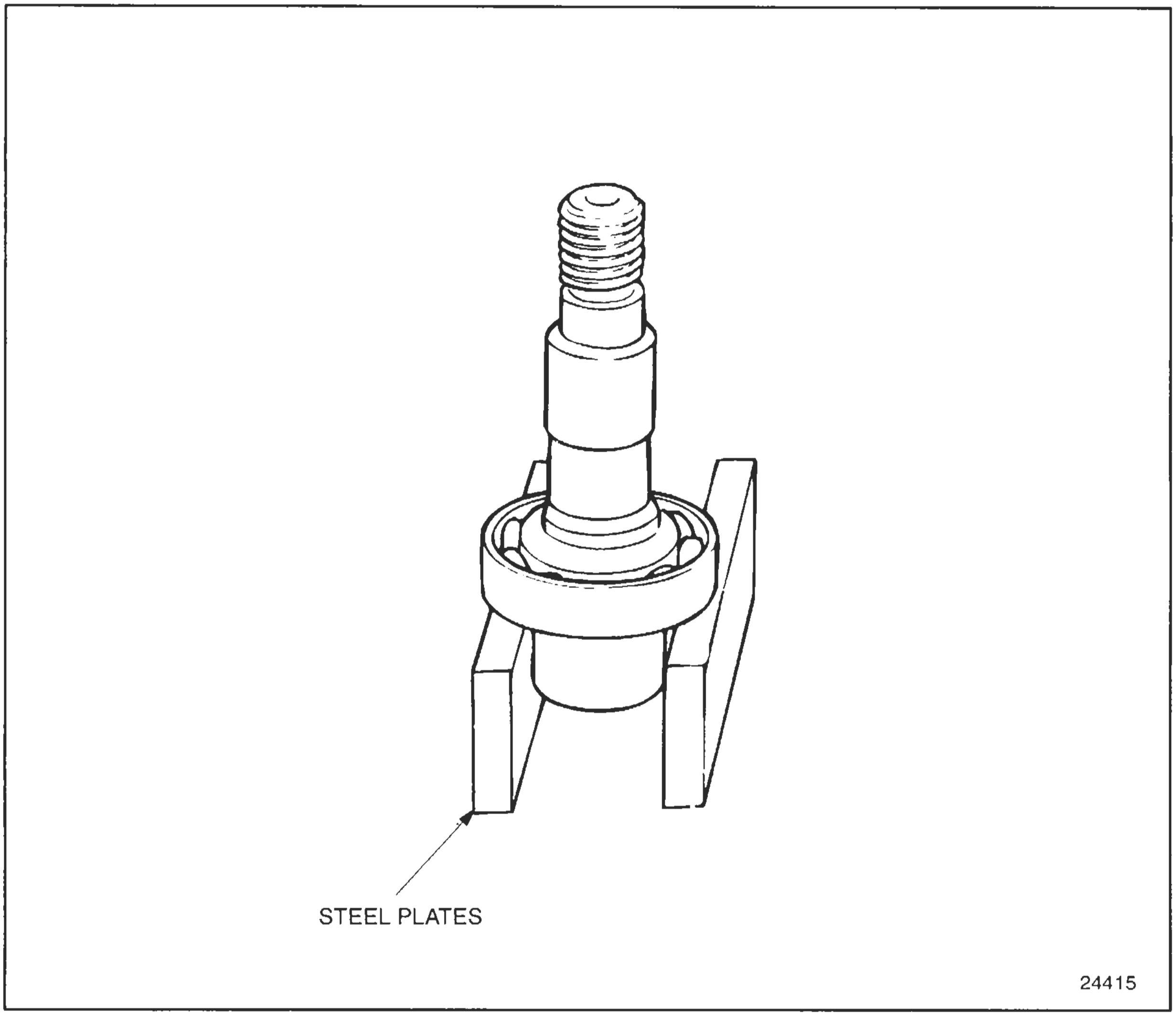


Figure 1–354 Ball Bearing Removal

NOTE:
Whenever the needle or ball bearing is removed from the shaft, they MUST be replaced with new bearing assemblies.

15. Use a press to apply pressure to the top of the shaft and remove the ball bearing from the shaft.

1.28.3.1 Inspection of the Accessory Drive

Clean the accessory drive prior to inspection as follows:

1. Clean all of the parts with clean fuel oil.

CAUTION:
To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

2. Dry parts with compressed air.

Inspect the accessory drive as follows:

1. Inspect the driveshaft for damage.
   [a] Check the driveshaft for galling, pitting, cracks, or other damage.
   [b] If any damage is detected, replace with a new part.

1.28.4 Assembly of the Accessory Drive

Assemble the accessory drive as follows:

1. Place a new ball bearing on the accessory driveshaft. Use tool J 36024-1A and a press to install the bearing onto the shaft until it bottoms out against the shoulder of the driveshaft. See Figure 1-355.

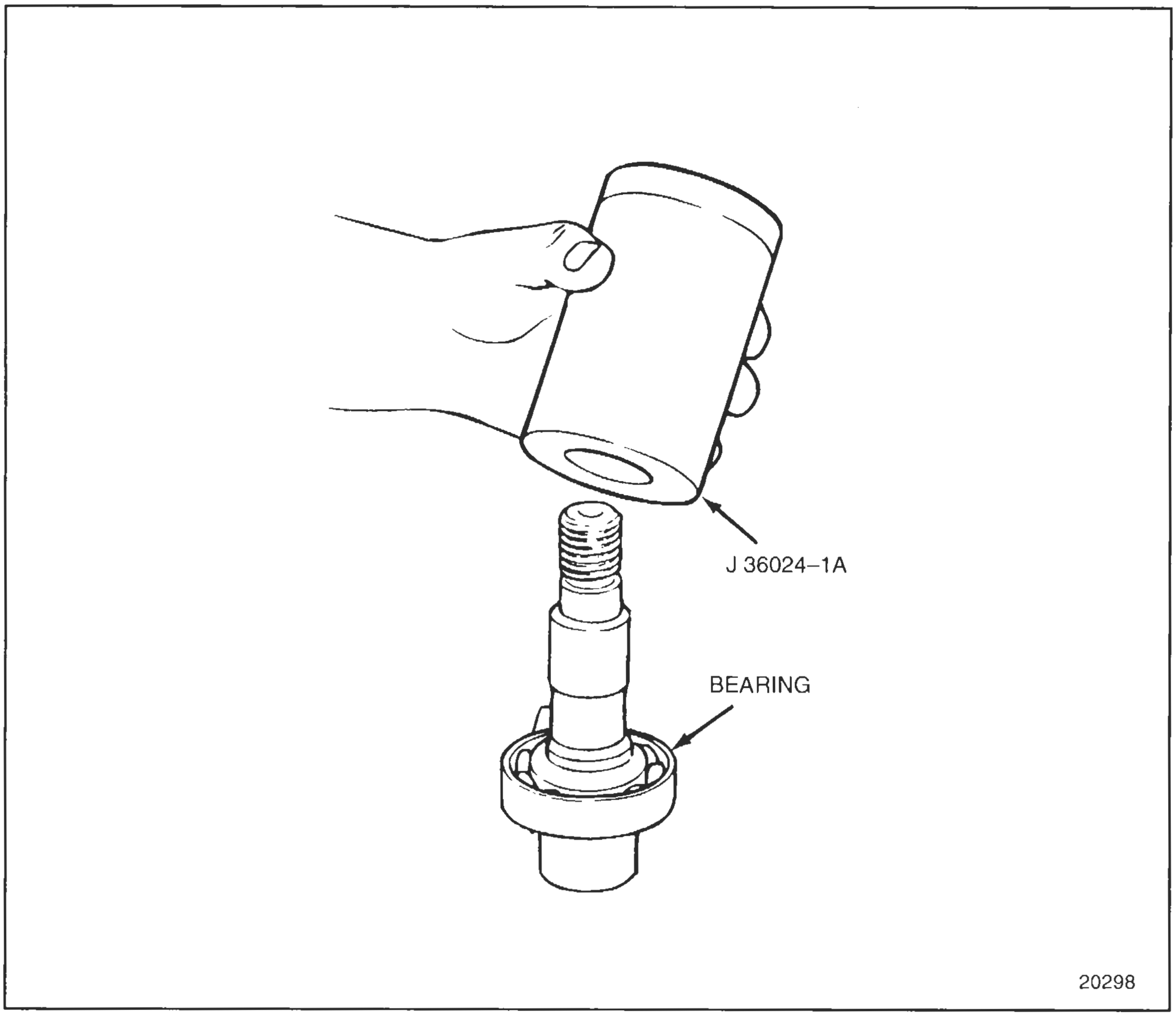


Figure 1–355 Bearing Installation

2. Install the snap ring to the accessory driveshaft making sure it is fully seated in the groove a full 360°. See Figure 1–356.

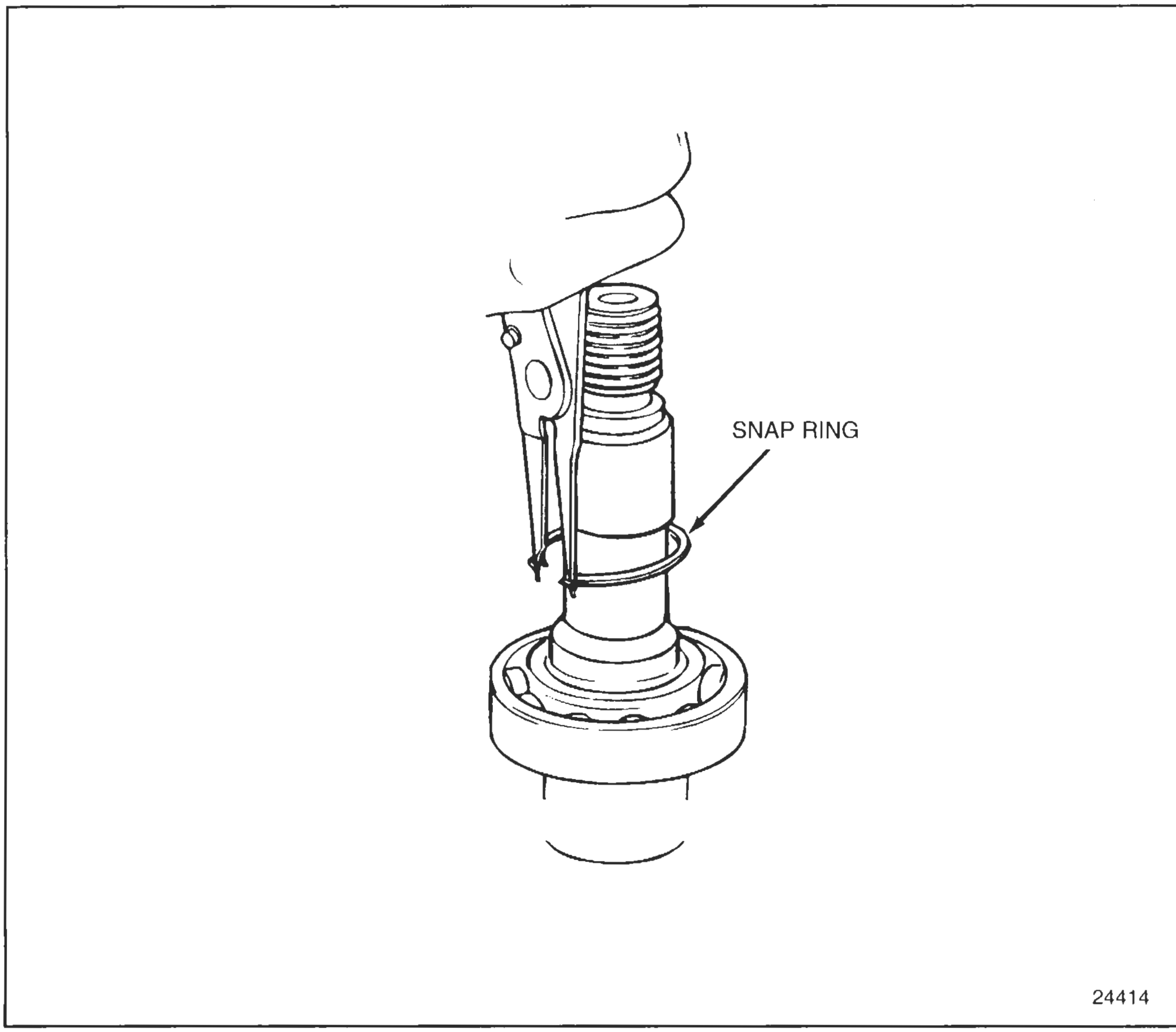


Figure 1–356 Snap Ring Installation

3. Place the needle bearing inner race on the accessory driveshaft. Use tool J 36024–1 and a press to install the bearing inner race to the shaft until it is tight against the shoulder. See Figure 1–357.

NOTE:
On current design accessory driveshaft, the needle bearing inner race is incorporated into the shaft.

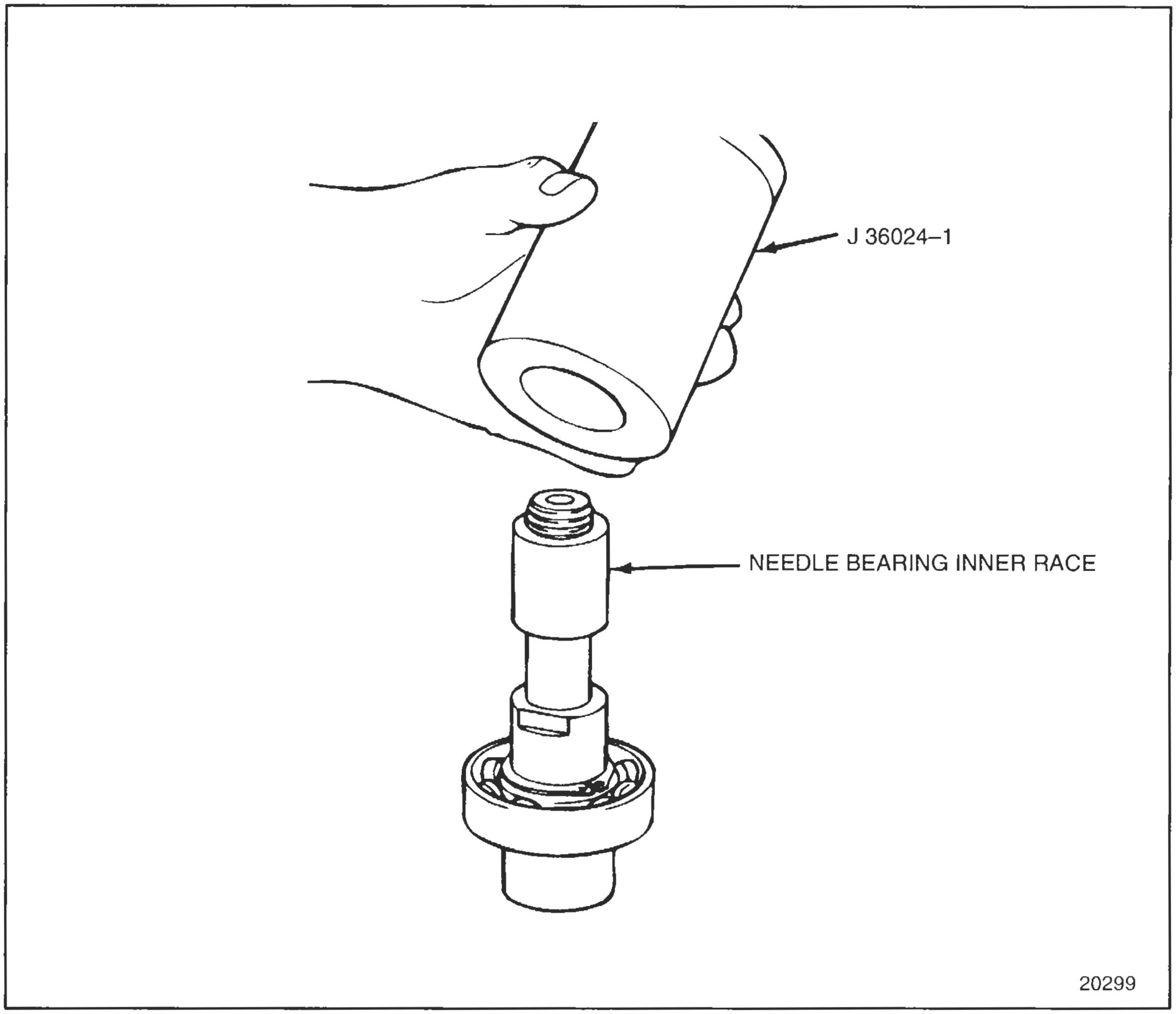


Figure 1–357 Bearing Inner Race Installation

4. Install the needle bearing to the accessory drive housing using tool J 36024-2 and a press. See Figure 1-358.

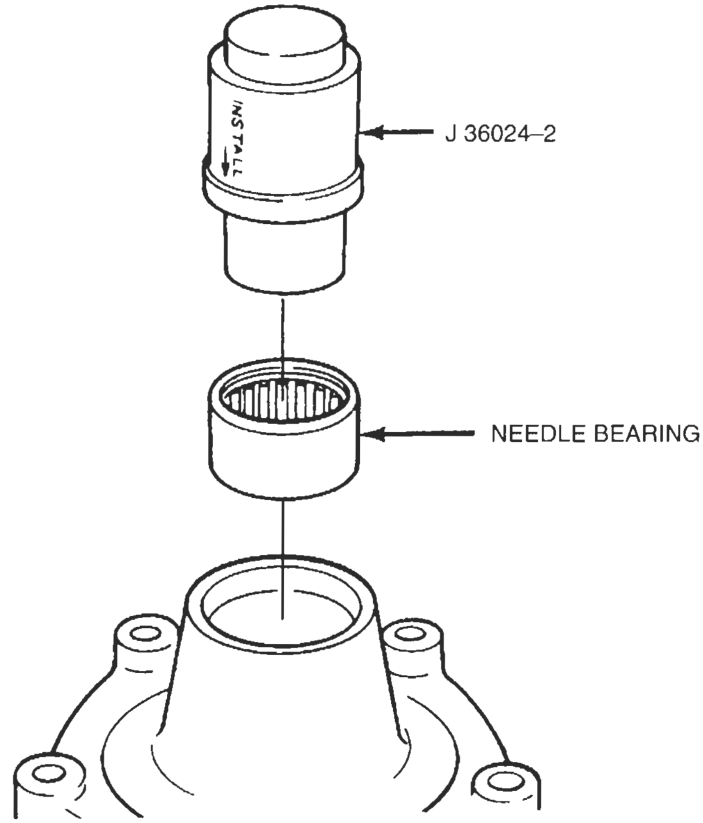


Figure 1–358 Needle Bearing Installation

NOTE:
The end of the bearing with the identification numbers must be against the installer.

NOTE:
The word INSTALL and an arrow are etched into the tool, J 36024–2, to facilitate correct bearing installation.

5. Lubricate the oil seal contact area of the accessory drive housing with a thin film of engine oil.

6. Install the accessory drive oil seal to the accessory drive housing using the seal installer, J 36024-4, and a plastic hammer or fiber mallet. The oil seal must be installed flush to 0.25 mm (.010 in.) below the face of the housing. See Figure 1-359.

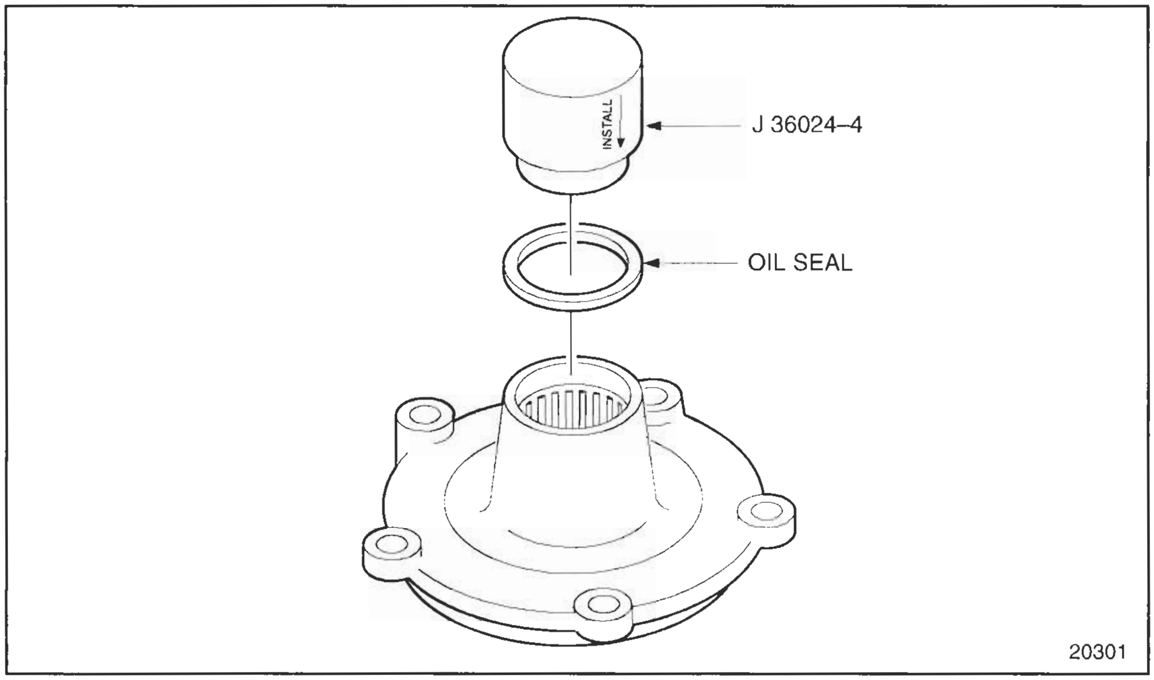


Figure 1-359 Accessory Drive Oil Seal Installation

7. Lubricate the oil seal with a thin film of engine oil.
8. Support the holding fixture, J 36024-3 on two steel plates and position the accessory drive housing into the hole in the fixture.

9. Install the driveshaft to the housing. See Figure 1–360.

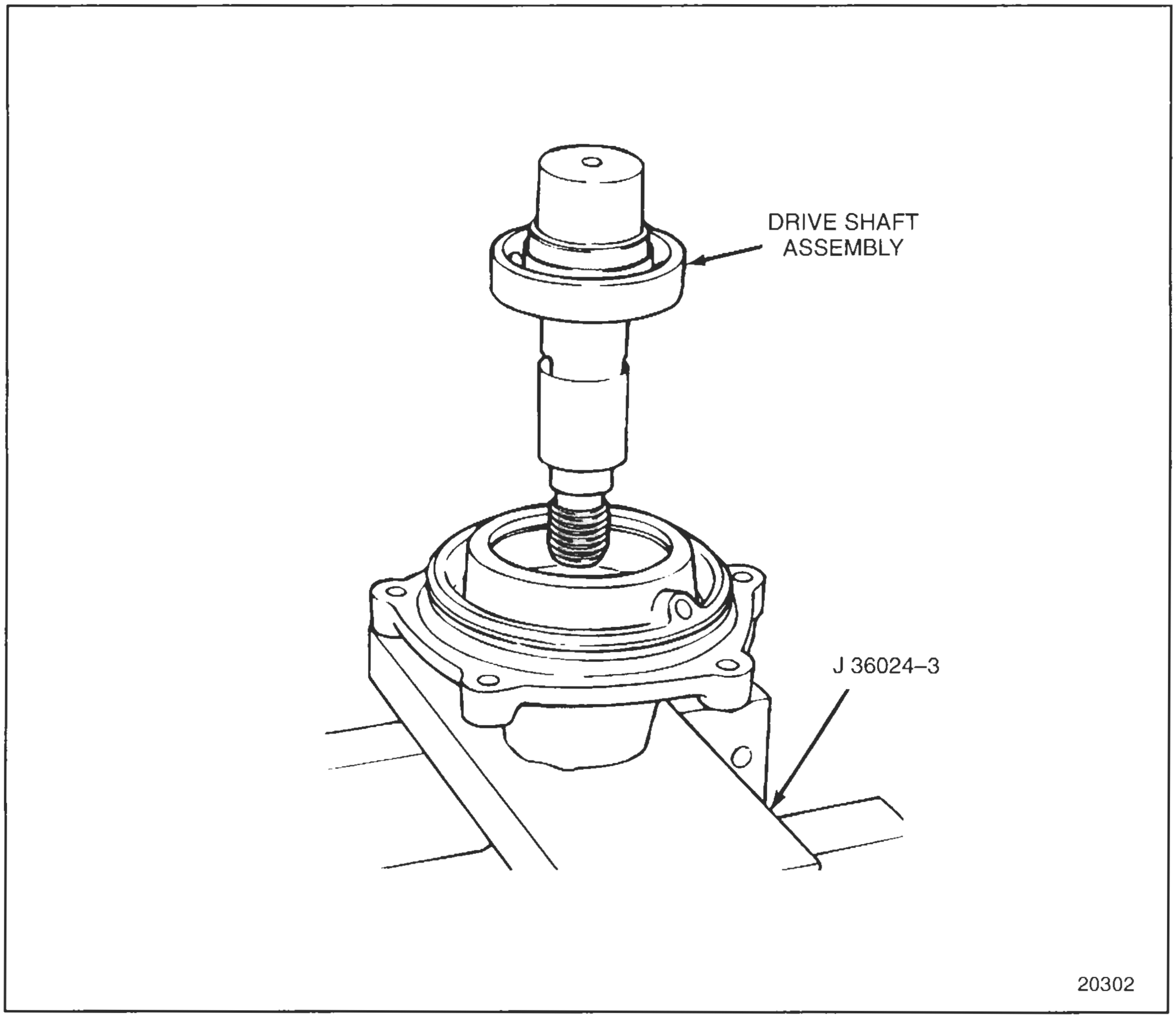


Figure 1–360 Accessory Driveshaft Preparation

10. Press the driveshaft into the housing by placing tool, J 36024–1A, on the bearing outer race.

11. Press the bearing into the housing until the bearing is seated against the shoulder of the housing. See Figure 1–361.

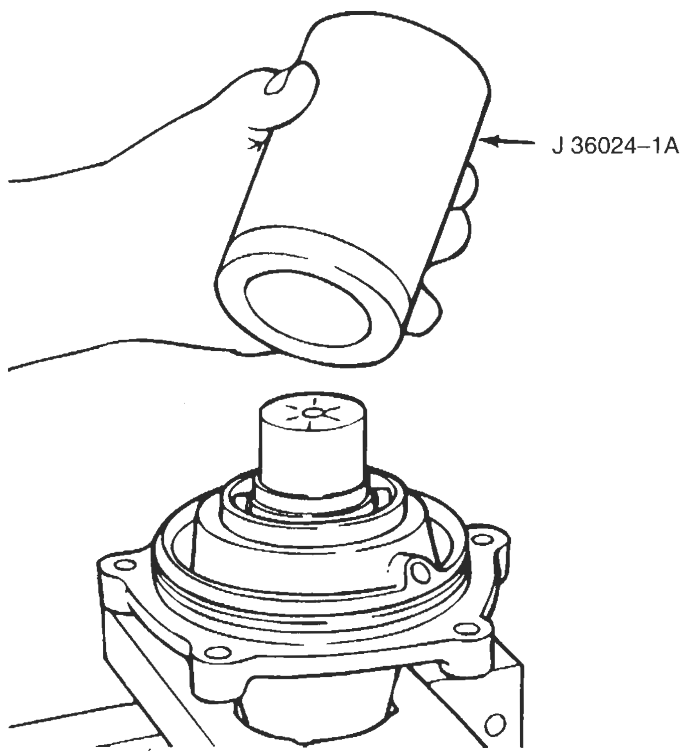


Figure 1–361 Accessory Driveshaft Installation

12. Install the snap ring to the accessory drive housing making sure the snap ring is fully seated in the groove a full 360°. See Figure 1–362.

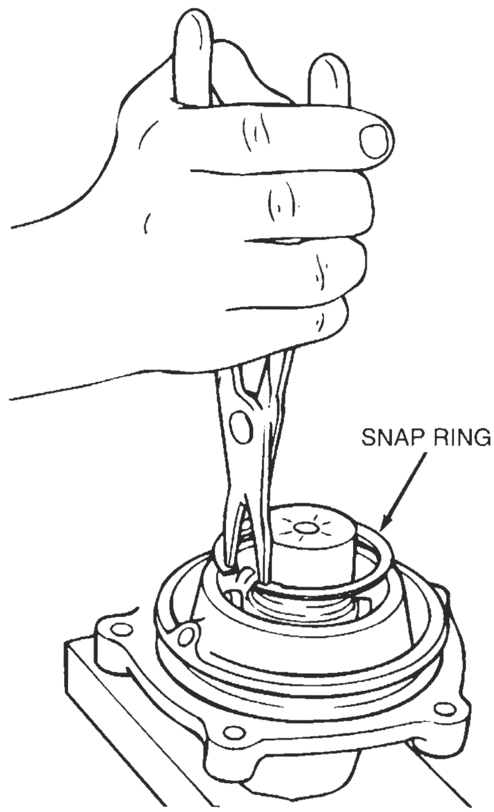


Figure 1–362 Snap Ring Installation

13. Lubricate the contact surfaces of the bearing with clean engine lubricating oil.

14. A film of lubriplate must be applied to the drive gear end of the accessory driveshaft. See Figure 1-363.

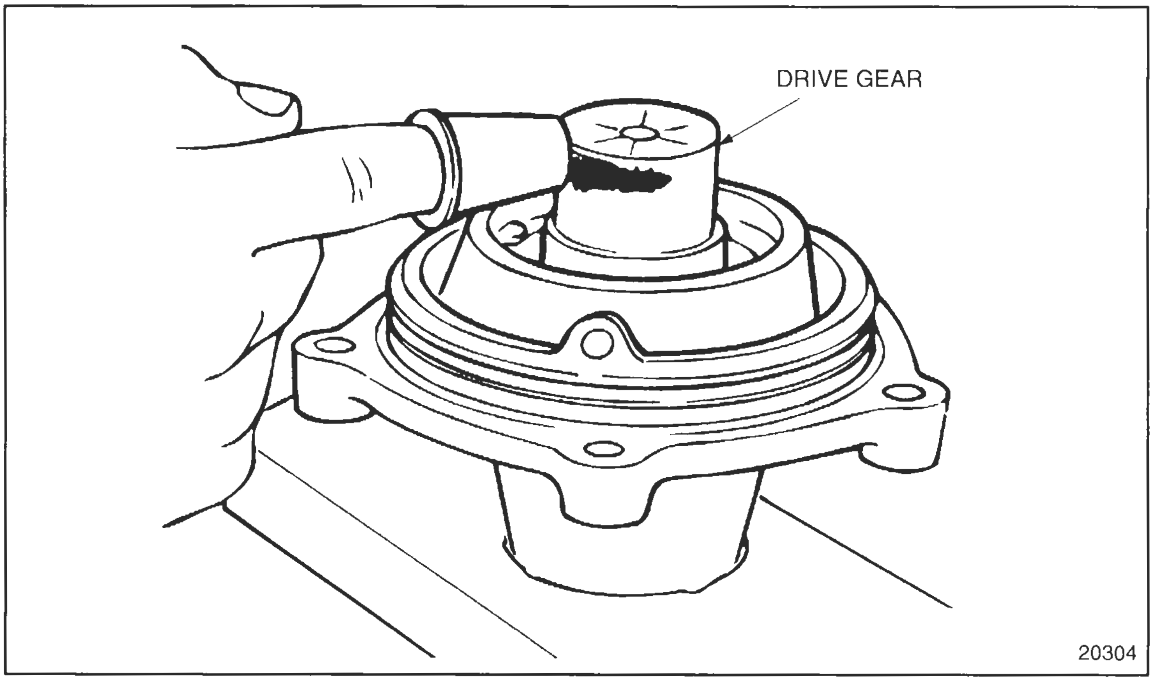


Figure 1–363 Drive Gear Installation Preparation

15. Use a press to install the drive gear on the accessory driveshaft until it is flush with the driveshaft end. Make sure the three threaded holes are facing up. See Figure 1–364.

NOTE:
Support the opposite end of the driveshaft on the press bed when pressing the gear on the shaft. A minimum press load of 17.8 kN (4000 lb) must be obtained when pressing the gear on the shaft.

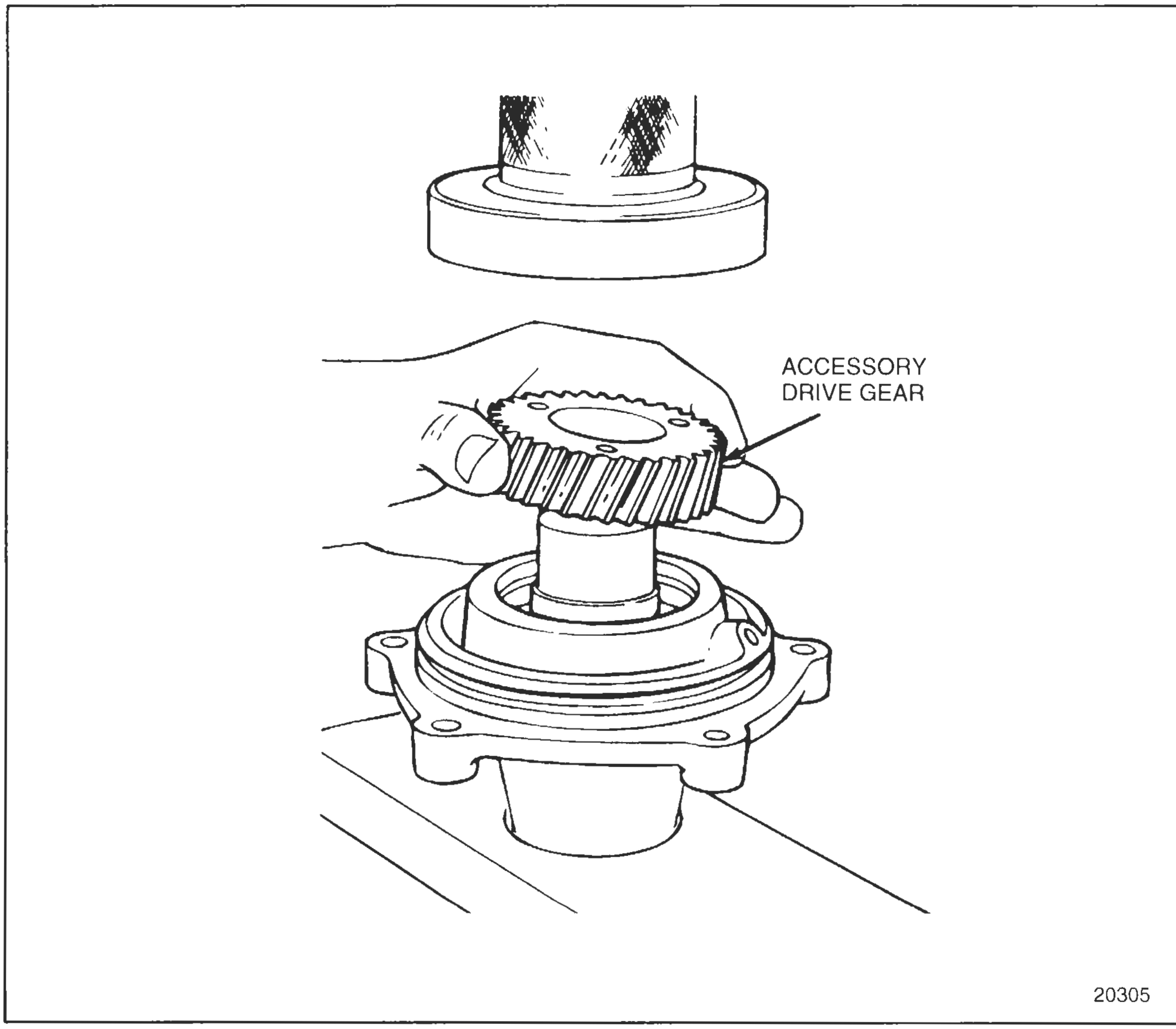


Figure 1–364 Accessory Drive Gear Installation

16. Install the accessory drive pulley to the shaft.

NOTE:
If necessary, use tool J 36024–1A to seat the pulley on the shaft. If pressing is necessary, the opposite (gear) end of the shaft must be supported during the pressing operation.

17. Attach the accessory drive holding fixture, J 36024-3, to the drive gear. See Figure 1-347.
18. Place the accessory drive assembly holding fixture into a vise.
19. Install and tighten the accessory drive pulley locknut to 220-250 N·m (162-184 lb·ft) torque. See Figure 1-365.

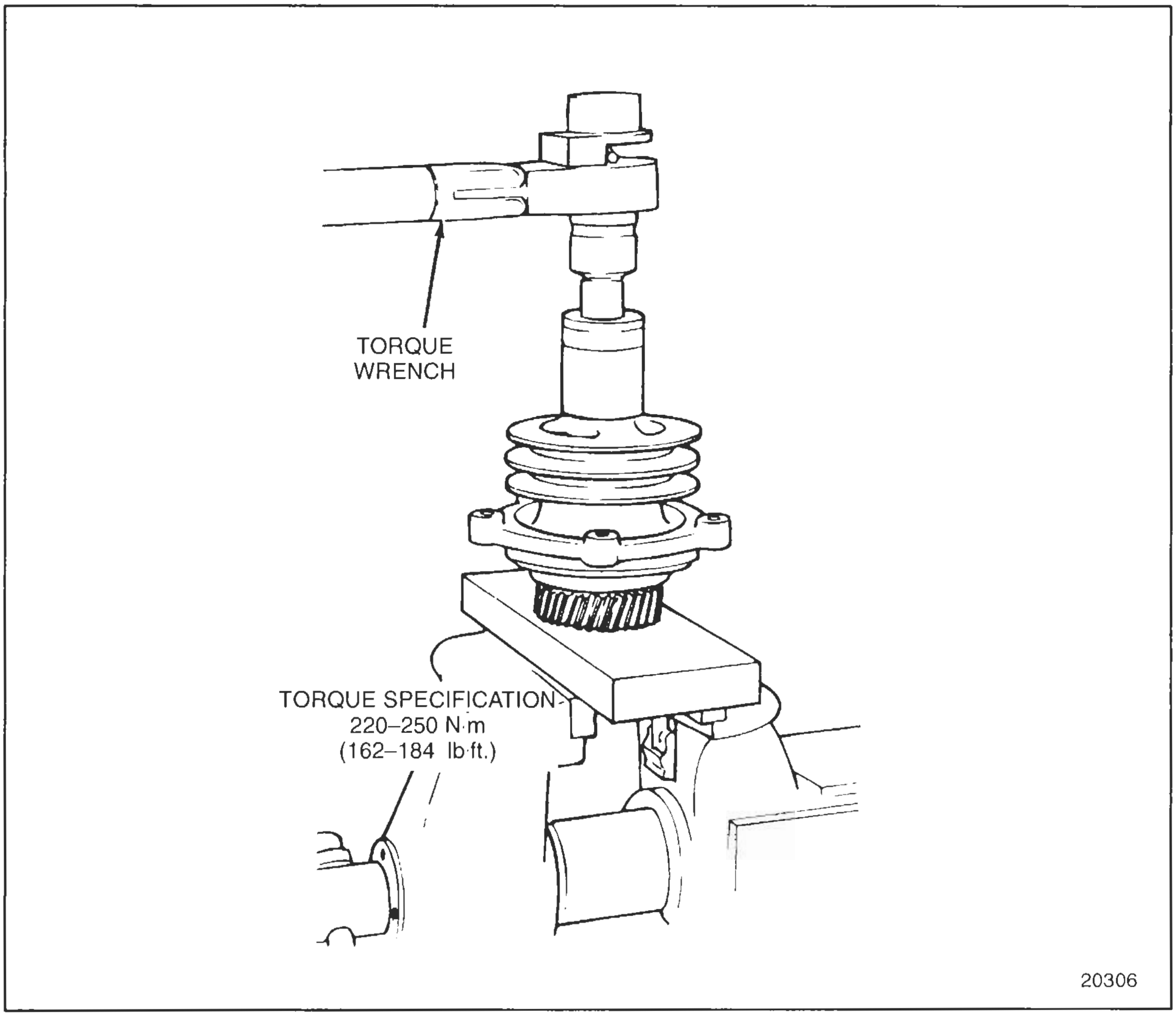


Figure 1-365 Accessory Drive Pulley Locknut Tightening

20. Support the accessory drive assembly. See Figure 1–366.

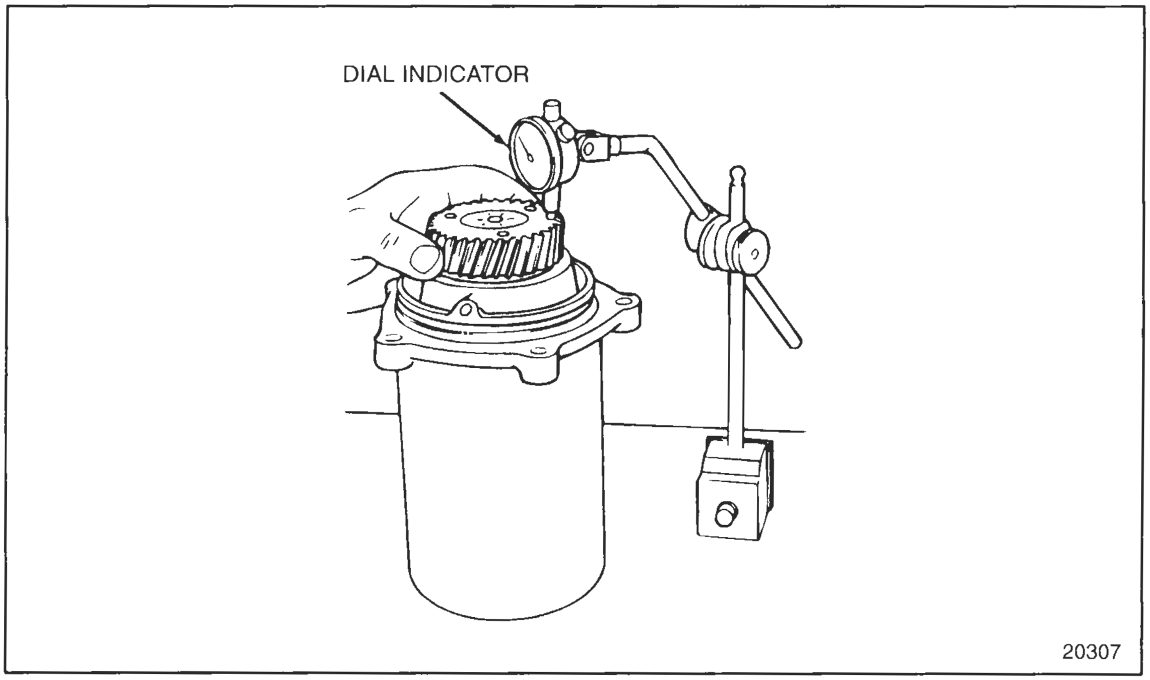


Figure 1–366 Accessory Drive Gear TIR Measurement

21. Assemble a dial indicator and magnetic base, so that the indicator stem rests on the face of the accessory drive gear just inboard of the drive gear teeth. See Figure 1–366.
22. Zero the dial indicator.
23. Rotate the drive gear two full rotations. See Figure 1–366. As the gear is rotated, the dial indicator needle may register both to the left and right of zero.
24. The total amount the dial indicator needle moves to the left and right of zero, added together, gives the total indicated runout (TIR). Allowable TIR is 0.04 mm (.0015 in.).

1.28.5 Installation of the Accessory Drive

Install the accessory drive as follows:

1. Install the O–ring seal in the groove on the drive housing.
2. Lubricate the O–ring with petroleum jelly.
3. Install the accessory drive housing to its original position in the gear case cover.

NOTE:
The word "UP" is cast into the drive housing.

4. Install the bolts that secure the accessory drive housing to the gear case cover and tighten to 30–38 N·m (22–28 lb·ft) torque using the pattern. See Figure 1–367.

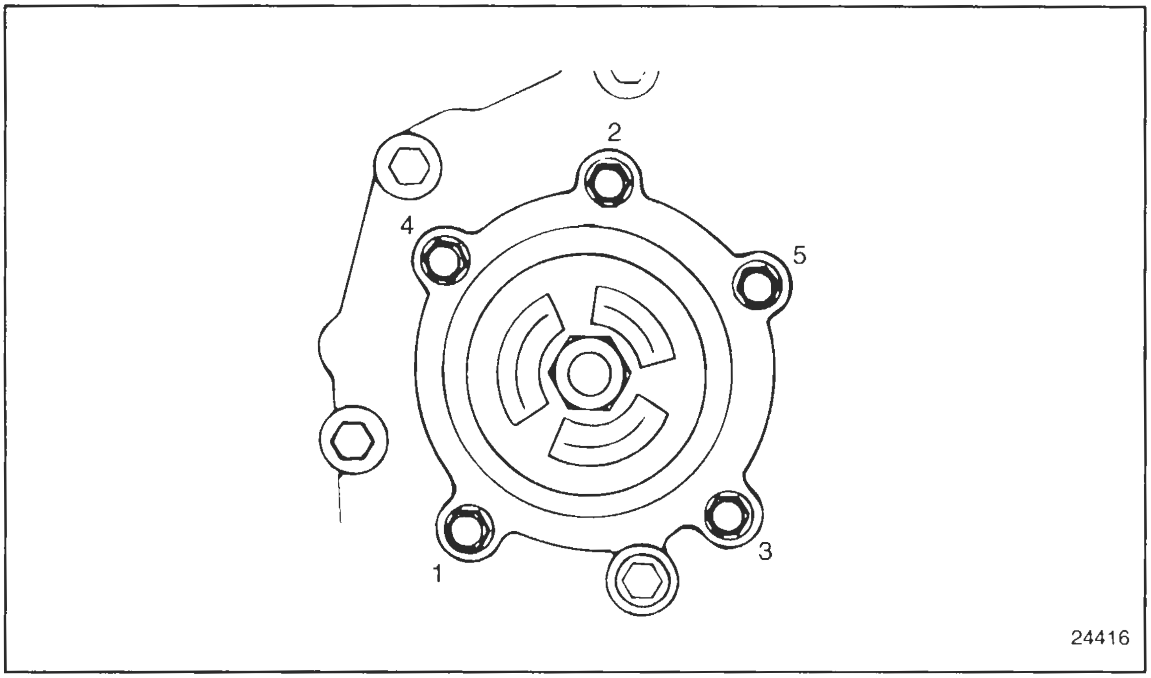


Figure 1–367 Accessory Drive Housing Bolt Torque Sequence

5. Check the bull gear–to–accessory drive gear backlash. Refer to section 1.21.2.1.
6. Adjust the alternator belts. Refer to section 13.5.7. Tighten the alternator mounting bolts.
7. Install any other components removed for this procedure.

1.29 JAKE BRAKE

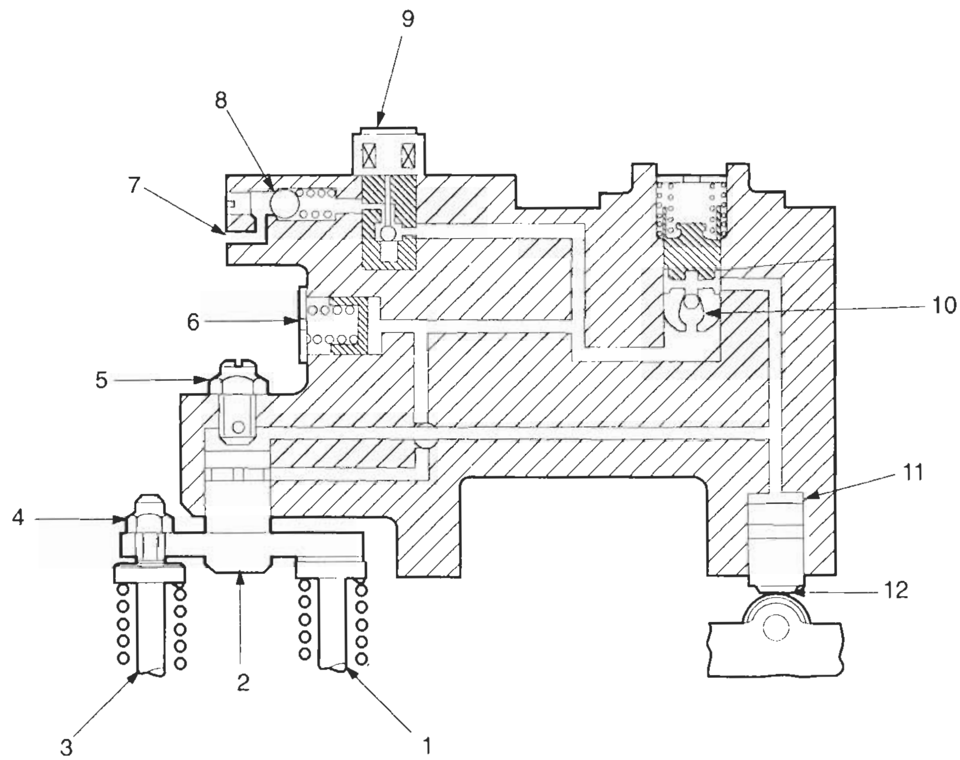
This section contains installation and maintenance information for the model 750 Jake Brake compression on engine retarder. This model was specifically designed for the Series 50 Engines. Listed in Table 1–5.

NOTICE:
Only the specific brake model can be used with the engine model it was designed for. Also, the correct slave piston adjustment specification must be used. Failure to follow these instructions may result in serious engine or engine brake damage.

Model No.	Model Year	Engine Displacement	Engine Brake	Slave Piston Adjustment
6047GU60, 6047GU28, 6047GU26, 6047GK28, 6047GK60, and 6047GK26	All	8.5L	750	0.660 mm (.026 in.)

Table 1–5 Jake Brake Model Information

Energizing the engine brake effectively converts a power–producing diesel engine into a power–absorbing air compressor. This is accomplished through motion transfer using a master–slave piston arrangement which opens cylinder exhaust valves near the top of the normal compression stroke, releasing the compressed cylinder charge to exhaust. See Figure 1–368.



1. Exhaust Valve
2. Slave Piston Assembly
3. Exhaust Valve
4. Leveling Screw
5. Slave Piston Adjusting Screw (Reset)
6. Accumulator
7. Oil In
8. Check Valve (Model 760)
9. Solenoid Valve
10. Control Valve
11. Master Piston
12. Injector Pin and Roller

Figure 1–368 Model 750 Jake Brake Schematic

The blowdown of compressed air to atmospheric pressure prevents the return of energy to the engine piston on the expansion stroke, the effect being a net energy loss, since the work done in compressing the cylinder charge is not returned during the expansion process.

Exhaust blowdown occurs as the energized solenoid valve permits engine lube oil to flow under pressure through the control valve to both the master piston and the slave piston. See Figure 1–368.

Oil pressure causes the master piston to move down, coming to rest on the injector rocker arm roller.

The injector rocker arm begins its travel as in the normal injection cycle, moving the master piston upward and directing high–pressure oil to the slave piston. The ball check valve in the control valve imprisons high–pressure oil in the master–slave piston system.

High pressure oil causes the slave piston to move down, momentarily opening the exhaust valves, while the engine piston is near its top dead center position, releasing compressed cylinder air to the exhaust manifold.

At the bottom of its stroke the slave piston separates from the valve in the slave piston reset adjusting screw allowing high pressure oil to flow into the accumulator. This reduces the pressure in the high pressure circuit, permitting the slave piston to retract and the exhaust valves to close in preparation for the normal exhaust valve cycle. The oil pressure reserved in the accumulator insures that the hydraulic circuit is fully charged for the next cycle. Compressed air escapes to the atmosphere completing a compression braking cycle.

Control of the Jake Brake is fully electronic. Wiring of the Jake Brake control system will vary depending on the vehicle manufacturer. A typical installation of the Jake Brake control system. See Figure 1–369.

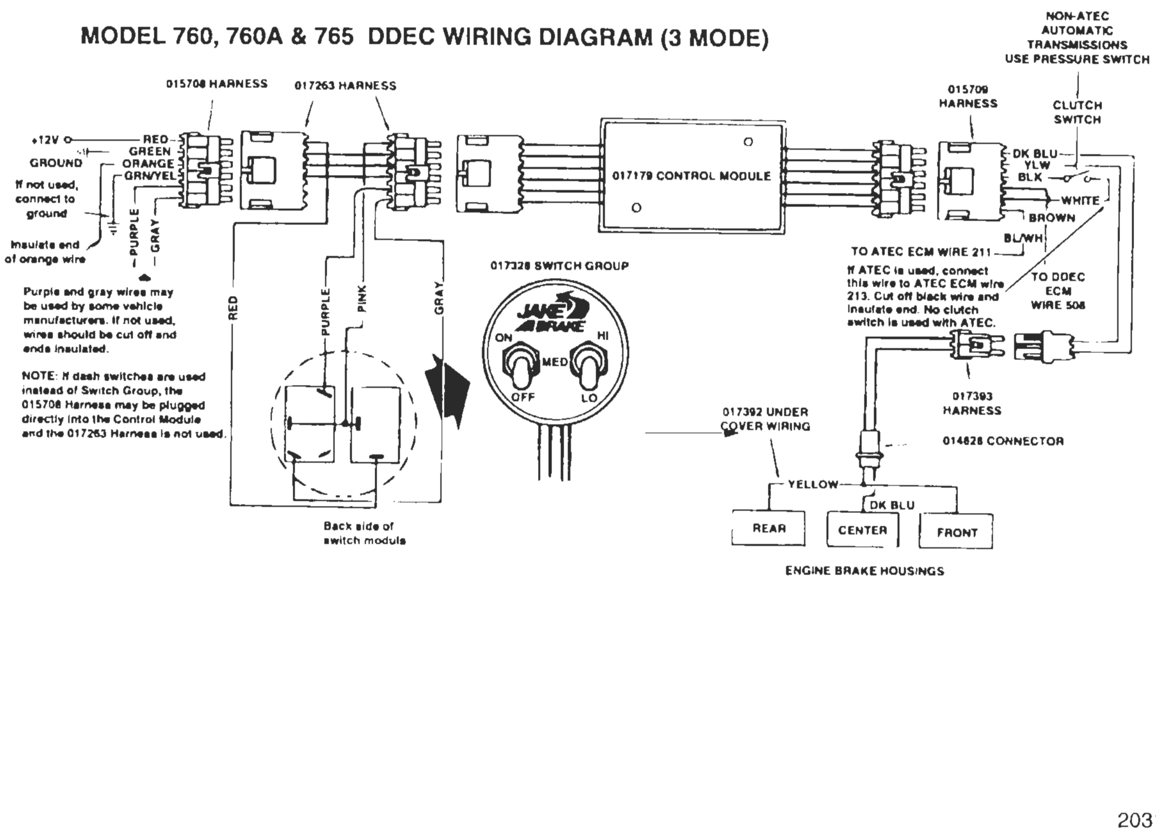


Figure 1–369 Jake Brake Control System

1.29.1 Repair or Replacement of Jake Brake

Detroit Diesel does not service the Jake Brake. For Jake Brake service procedures, refer to original equipment manufacturer specifications.

1.29.2 Cleaning and Removal of Jake Brake

Precleaning is not necessary.

Remove the Jake Brake as follows:

1. Disconnect starting power for engine. Refer to section 8.1.
2. Remove the engine rocker cover. Refer to section 1.6.2.
3. Disconnect the solenoid wiring harness connectors from the engine brake solenoids. See Figure 1–370.

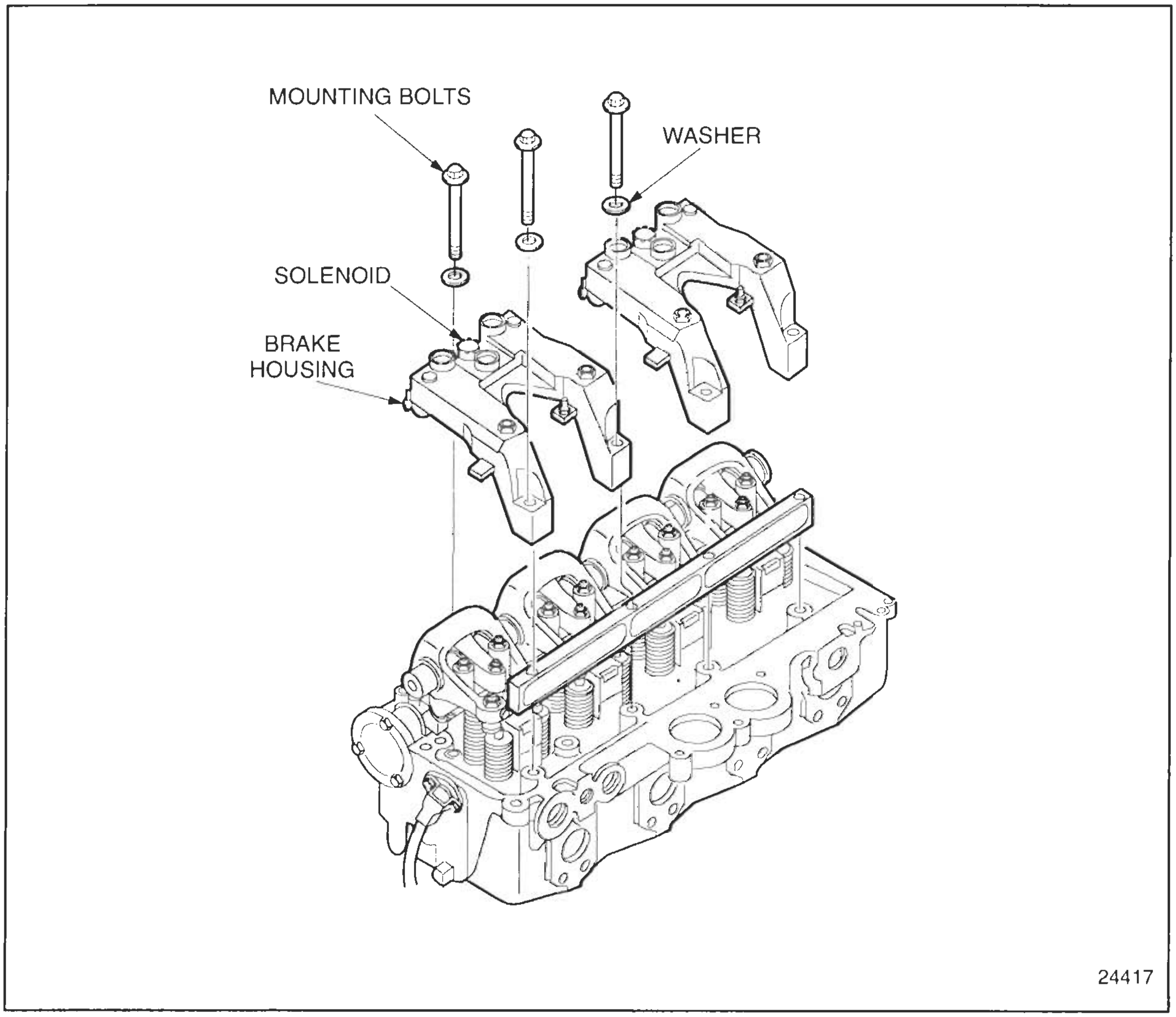


Figure 1–370 Jake Brake Assembly

4. Remove the six bolts and washers that secure the engine brake assemblies to the cylinder head.
5. Remove the engine brake assemblies and the spacer bar.

1.29.2.1 Inspection of the Jake Brake

Detroit Diesel does not service the Jake Brake. Refer to OEM to determine if the Jake Brake can be repair or if replacement is necessary.

1.29.3 Installation of the Jake Brake

Install the Jake Brake as follows:

1. Adjust the intake and exhaust valve clearances and set the injector heights. Refer to section 1.12.2.

CAUTION:

Eye protection must be worn while blowing the oil from the bolt holes. Personal injury may result if safety glasses are not worn.

2. Attach the length of tubing to a blow gun nozzle, and blow out the oil from the bolt holes.
3. Cover the holes with hand towels to minimize oil spray.

NOTE:
Removing the oil from the bolt holes prevents the cylinder head from cracking when tightening the bolts.

4. Place the spacer bar on the exhaust manifold side of the cylinder head with the "out" markings adjoining each other and facing the exhaust manifold. See Figure 1–371.

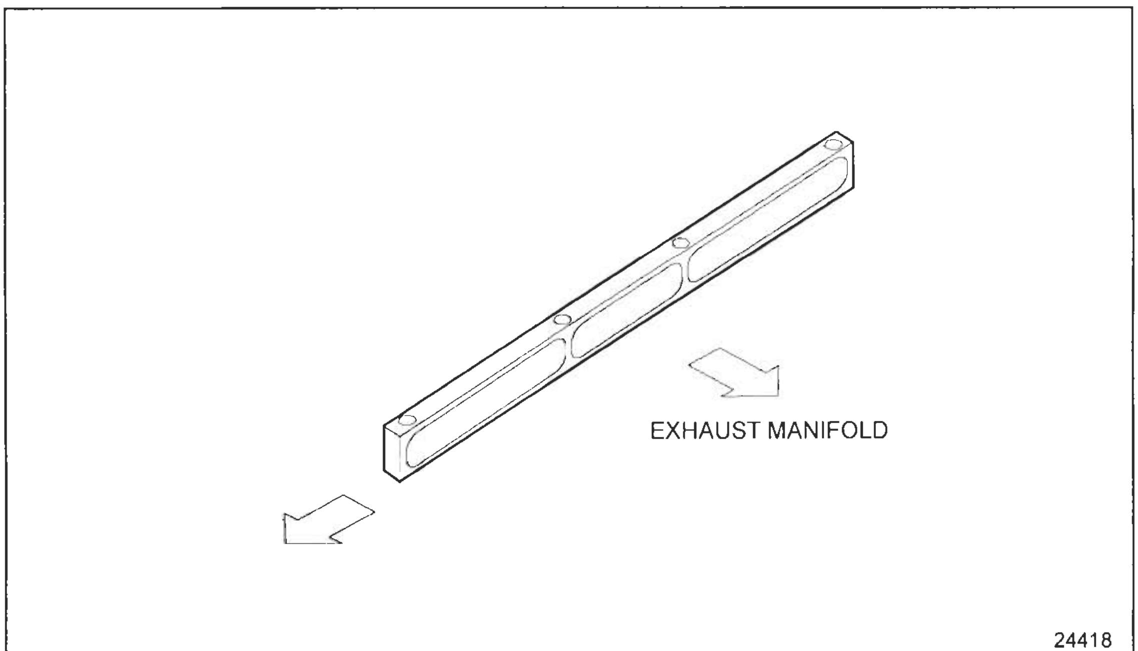


Figure 1–371 Jake Brake Spacer Bar Installation

5. Place the three engine brake housings over the rocker arm shafts with the solenoid valves toward the camshaft side of the engine.

NOTE:
Be sure housings do not interfere with wiring harness.

CAUTION:

Do not mix the rocker arm shaft bolts and the Jake Brake mounting bolts. If the rocker arm shaft bolt is mistakenly used to mount the Jake Brake housing, the longer shoulder on the bolt will block the oil supply to the Jake Brake on the camshaft side of the housing. The brake will not retard the engine as designed. This condition could cause loss of vehicle braking control on downgrades, resulting in personal injury and vehicle damage.

6. Install washers onto mounting bolts and insert into brake housing.

NOTE:
The rocker arm shaft mounting bolt and Jake Brake mounting bolt, part of the Jake Brake Assembly, are similar in appearance. Both are M12 x 110 mm (4.33 in.) long and have 12 point heads.

NOTE:
In the event of a failure of housing hold down bolt on a Model 750/760/760A/765 housing, the corrective action is to replace all three bolts on that particular housing.

[a] The Jake Brake bolt has the Jacobs logo (circled "J") and the bolt length (110 mm) marked on it head.

[b] The DDC rocker arm shaft bolt has the DDC logo (spinning arrows) and the vendor I.D. (F–C) on its head.

NOTE:
Be sure that only Jake Brake bolts, see Figure 1–372, are installed in the Jake Brake housing.

[c] The DDC bolt shoulder is much longer, 17.0 mm (.669 in.) versus 4 mm (.157 in.) for the Jake Brake bolt. See Figure 1–372.

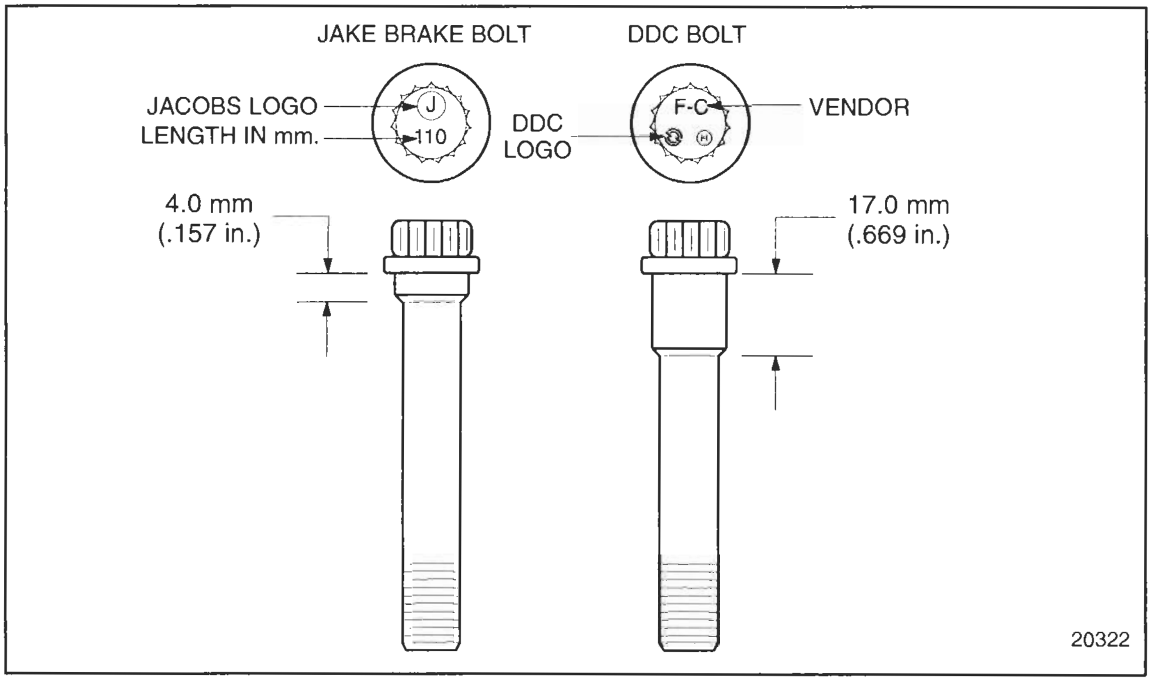


Figure 1–372 Jake Brake Bolt Identification

7. Before tightening the engine brake hold–down cap screws, move the housing from side to side, and locate the housing in the center position.
8. Tighten the engine brake mounting bolts using the following sequence:
   [a] Torque the three bolts on the camshaft side of the engine to 55 N·m (40 lb·ft).
   [b] Torque the six bolts on the exhaust manifold side of the engine to 55 N·m (40 lb·ft).
   [c] Repeat the tightening sequence and retorque all bolts to 135.6 N·m (100 lb·ft).
   [d] Secure wire harness to spacer bars with plastic ties.
9. Connect wiring harness solenoid connectors to solenoids.
10. Adjust the slave piston clearance (Jake Brake Lash) as stated in the OEM.
11. Install the valve rocker cover. Refer to section 1.6.4.
12. Install any other components that were removed for this procedure.
13. Connect starting power for the engine.

1.A ADDITIONAL INFORMATION

SHOP NOTES

Shop notes contains information on checking bearing clearances, the crankshaft remanufacturing procedures and a glossary.

Cylinder Block Liner Boring

Further information will be printed as it is developed.

Checking Bearing Clearance

A strip of soft plastic squeezed between the crankshaft journal and the connecting rod bearing or main bearing may be used to measure the bearing clearances.

The strip is a specially molded plastic "wire manufactured commercially and is available in three sizes and colors. Type PG–1 (green) has a clearance range of 0.0254–0.0762 mm (.001–.003 in.). Type PR–1 (red) has a range of 0.0508–0.1524 mm (.002–.006 in.). Type PB–1 (blue) has a range of 0.1016–0.2286 mm (.004–.009 in.).

The plastic strip may be used for checking the bearing clearances as follows:

1. Remove the bearing cap and wipe the oil from the bearing shell and the crankshaft journal to be checked.

NOTE:
Check the main bearing clearances with the weight of the crankshaft supported by a jack under the counterweight adjoining the bearing being checked. If the engine is positioned with the main bearing caps supporting the crankshaft and flywheel, an erroneous reading could result.

2. Place a piece of plastic strip the full width of the bearing shell, about 1/4 inch off center. See Figure 1–373.

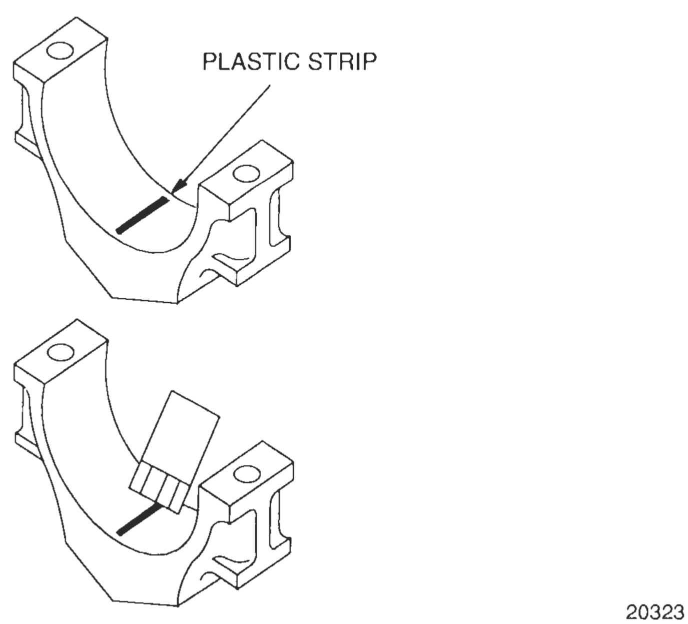


Figure 1–373 Using Plastic Strip to Measure Bearing–to–Crankshaft Clearance

3. Install the bearing cap. Tighten the bolts to 470–530 N·m (347–391 lb·ft) torque.
4. Remove the bearing cap. The flattened plastic strip will be found adhering to either the bearing shell or the crankshaft.
5. Compare the width of the flattened plastic strip at its widest point with the graduations on the envelope. See Figure 1–373. The value within the graduation on the envelope indicates the bearing clearance in thousands of an inch. To obtain metric specifications:
   [a] Multiply the reading obtained (in thousandths) by 25.4. Taper may be indicated when one end of the flattened plastic strip is wider than the other.
   [b] Measure each end of the plastic strip. The difference between the two readings is the approximate amount of taper.

CRANKSHAFT REMANUFACTURING PROCEDURES

This section describes the procedures used to remanufacture crankshafts.

Crankshaft Grinding

In addition to the standard size main and connecting rod bearings, 0.25 mm, 0.50 mm and 0.75 mm (approx. .010 in., .020 in., and .030 in.), undersize bearings listed in Table 1-6 are available.

Crankshafts which exhibit surface irregularities may be reground to utilize these bearings. Listed in Table 1-6, are guidelines to determine if the crankshaft is suitable for regrinding:

Bearing Size	Connecting Rod Journal Diameter	Main Bearing Journal Diameter
Standard	85.000–84.975 mm (3.346 in.–3.345 in.)	125.000–124.975 mm (4.921 in.–4.920 in.)
0.250 mm (.010 in.)Undersize	*84.750–84.775 mm (3.336 in.–3.337 in.)	*124.750–124.725 mm (4.911 in.–4.910 in.)
0.500 mm (.020 in.)Undersize	*84.500–84.475 mm (3.327 in.–3.326 in.)	*124.500–124.475 mm (4.902 in.–4.901 in.)
0.750 mm (.030 in.)Undersize	*84.250–84.225 mm (3.317 in.–3.316 in.)	*124.250–124.225 mm (4.892 in.–4.891 in.)

*Dimension of reground crankshaft.

Table 1–6 Crankshaft Journal Specifications

Inspection

Perform the following steps for part inspection:

1. Determine if the crankshaft is from a Series 50 Engines. Listed in Table 1-7.

Model	Forging Part Number	Year Released	Fillet Finishing
8.5L Liter	23511363	1993	Induction Hardened
8.5L Liter	23515595	1994	Induction Hardened

Table 1–7 Crankshaft Part Number History

2. Inspect connecting rod and main bearing journals for discoloration due to excessive overheating from bearing failure.

NOTE:
Crankshafts with discoloration are not acceptable for rework.

3. Inspect keyway conditions using width gages and micrometers. Compare with the specifications. See Figure 1–374.

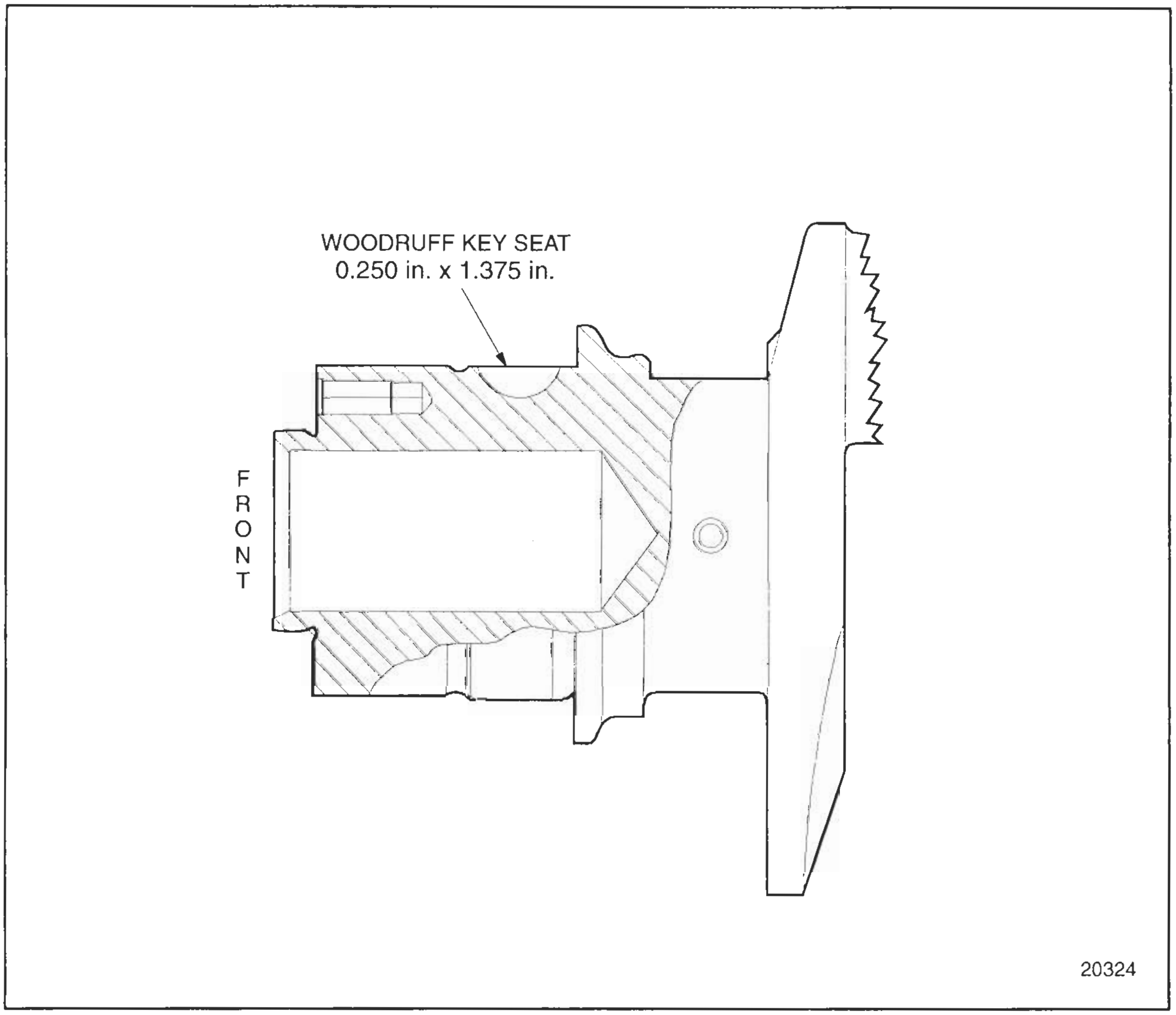
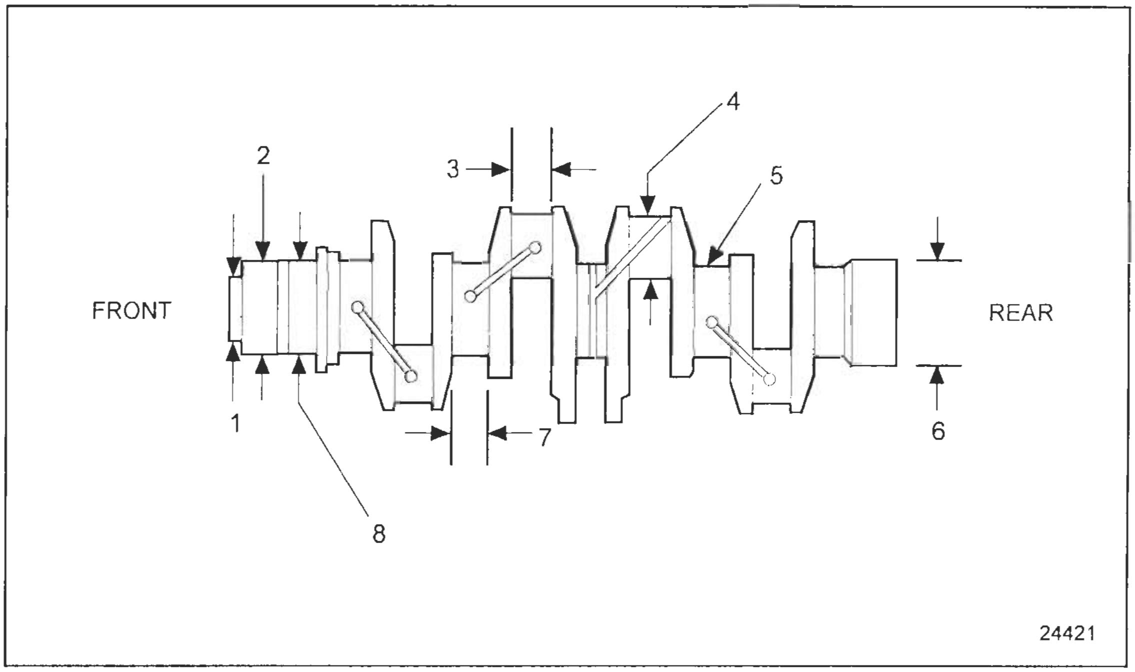


Figure 1–374 Standard Crankshaft Keyway Dimensions

4. Inspect flange bolt holes visually and determine if any necessary repairs can be made by chasing threads or installing Heli–coil(s).

5. Regardless of seal area wear condition, a new sleeve and seal must be installed. See Figure 1–375.



1. 80.19–80.22 mm (3.157–3.158 in.)
2. 131.72–131.78 mm (5.186–5.188 in.)
3. 55.77–55.87 mm (2.196–2.200 in.)
4. 84.975–85.00 mm (3.345–3.346 in.)
5. 49.45–49.55 mm (1.947–1.950 in.)
6. 131.72–131.78 mm (5.186–5.188 in.)
7. 49.35–49.65 mm (1.943–1.955 in.)
8. Crankshaft Timing Gear Contact Surface Diameter

Figure 1–375 Standard Crankshaft Dimensions

6. Read and record all "bearing" total indicator reading (TIR) measurements with the crankshaft mounted in vee-blocks. Listed in Table 1–8 are TIR limits.

NOTE:
Runout tolerance listed in Table 1–8 are given for guidance when regrinding crankshaft. When the runout on adjacent journals is in the opposite direction, the sum must not exceed 0.075 mm (.003 in.) total indicator reading. When the runout on adjacent journals is in the same direction, the difference must not exceed 0.075 mm (.003 in.) total indicator reading.

Journals Supported on	Journals Measured	Maximum Run–Out (Total Indicator Reading)
No. 1 and No. 5	No. 2 and No. 4	0.050 mm (.002 in.)
No. 1 and No. 5	No. 3	0.075 mm (.003 in.)

Table 1–8 Bearing Total Indicator Reading (TIR) Specifications

7. Whether runout on adjacent journals is in the same or opposite directions, the sum shall not exceed 0.075 mm (.003 in.) TIR.
8. When high spots of runout adjacent journals are at right angles to each other, the sum shall not exceed 0.10 mm (.004 in.) TIR or 0.05 mm (.002 in.) on each journal.
9. In the event of bearing seizure, bearing overlay must be removed. Check the width of journals to determine whether the sidewalls can be reground. See Figure 1-375.
10. Visually inspect the entire crankshaft for any serious deviations from normal wear patterns, cracks, nicks or other damage.
11. If the crankshaft has been ground undersize prior to present receiving inspection, check fillets, thrust, and all widths to determine whether or not enough stock remains to warrant regrinding. Listed in Table 1-9 are crankshaft specifications.

Crankshaft Specifications	Minimum	Maximum	Tolerance
Journal Diameter– Main Bearing	124.975 mm (4.920 in.)	125.000 mm (4.921 in.)	0.025 mm (.001 in.)
Journal Diameter– Connecting Rod Bearing	84.975 mm (3.345 in.)	85.000 mm (3.346 in.)	0.025 mm (.001 in.)
Journal Out–of–Round– Main Bearing	–	0.012 mm (.0005 in.)	0.012 mm (.0005 in.)
Journal Out–of–Round–Connecting Rod Bearing	–	0.008 mm (.0003 in.)	0.008 mm (.0003 in.)
Journal Taper * – Main Bearing	–	0.012 mm (.0005 in.)	0.012 mm (.005 in.)
Journal Taper *–Connecting Rod– Full Length	–	0.008 mm (.0003 in.)	0.008 mm (.0003 in.)
Journal Taper * Connecting Rod Half–Length	–	0.004 mm (.00016 in.)	0.004 mm (0.00016 in.)
Gear Fit Runout TIR (Total Indicated Reading)	–	0.038 mm (.0015 in.)	0.038 mm (.0015 in.)
Journal Alignment–Main and Connecting Rod– Per Length of Pin	–	0.012 mm (.0005 in.)	0.012 mm (.0005 in.)
Axial Profile Slope–Main – Full Length	–	0.008 mm (.0003 in.)	0.008 mm (.0003 in.)
Axial Profile Slope–Mains Per 5.0 mm (.197 in.) of Length	–	0.006 mm (.00024 in.)	0.006 mm (.00024 in.)
Axial Profile Slope–Connecting Rod Journals–Full Length	–	0.006 mm (.0002 in.)	–
Axial Profile Slope– Connecting Rod Journals– Per 50 mm (.197 in.) of Length	–	0.003 mm (.0001 in.)	–

Crankshaft Specifications	Minimum	Maximum	Tolerance
Main Fillet Radius	3.5 mm (.1378 in.)	4.0 mm (.1574 in.)	–
Connecting Rod Fillet Radius (23511363)	5.5 mm (.2165 in.)	6.0 mm (.2362 in.)	–
Connecting Rod Fillet Radius (23515595)	3.5 mm (.130 in.)	4.0 mm (.150 in.)	–
Surface Finish–Main and Connecting Rod Journals	–	0.3 µm 12AA	0.3 µm 12AA
Surface Finish–Thrust Wall	–	0.4 µm 16AA	0.4 µm 16AA
Surface Finish–Oil Seal Area	0.25 µm 10AA	0.63 µm 20AA	0.25 µm 10AA
Journal Hardness (Rockwell "C")	47 Rc	55 Rc	8 Rc
Crankshaft Dynamic Balance–(Ounce–Inch)	–	1.5	1.5
Main and Connecting Rod Journal Alignment Per Length of Pin	–	0.012 mm (.0005 in.)	–
Convex Crankshaft Butt Face Convex	–	0.013 mm (.0005 in.)	0.043 mm (.0017 in.)
Convex Crankshaft Butt Face Concave	–	0.03 mm (.0011 in.)	0.043 mm (.0017 in.)

*As Measured on Radial Basis

Table 1–9 Crankshaft Specifications

12. Journal O.D. score marks must be:
    [a] Circumferential–not axial.
    [b] Maximum of 0.254 mm (.010 in.) wide.
    [c] At least 3.175 mm (.125 in.) from fillet tangent point.
    [d] Smooth, no proud metal.
    [e] Maximum of one mark per journal.
13. No journal dimpling permitted for removal of defects.
14. Nicks, dents or pits in journal O.D. must be 3.175 mm (.125 in.) maximum diameter, no proud metal, maximum (3) per journal.
15. Pins and bearing journals which exhibit discoloration due to excessive overheating from bearing failure are not acceptable for rework.
16. If one or more main or connecting rod journals require grinding, then grind all of the main journals or all of the connecting rod journals to the same required size.
17. Inspect the hardness of all journals. Crankshafts to be 47–55 Rc.

18. Clean the crankshaft as follows:

[a] Clean all oil passages with a brush. Power probing is recommended.

[b] Remove all copper, brass and lead, etc., from journal surfaces. Scrub the crankshaft until clean in a detergent bath.

[c] Extremely rusted shafts can be soaked in hot rust stripper.

[d] Scrub all webs and counterweights with a wire brush to remove all blackened residue. Use industrial detergent at proper ratios or regular hot degreaser.

NOTICE:
A crack in any vital area of the crankshaft cannot be repaired or removed. That is why magnetic particle inspection of the entire crankshaft before regrinding is mandatory. Crankshafts that are cracked MUST BE SCRAPPED.

19. After a visual inspection, the crankshaft should be magnetically inspected using one of the two following methods:

[a] **Magnetic Particle Method:** Refer to section 1.7.2.6.

[b] **Fluorescent Magnetic Particle Method:** Refer to section 1.7.2.7.

MACHINING OPERATIONS

The following topics cover machining operations:

- ❑ Main And Connecting Rod Journals
- ❑ Grinding Connecting Rod Journals (Pins)
- ❑ Grinding Main Bearing Journals

Main and Connecting Rod Journals

To machine main and connecting rod journals, perform the following:

1. Connecting rod and main bearing journal grinding should be performed with crankshaft rotation opposite to actual engine rotation. See Figure 1–376.

NOTE:
Crankshaft and main journal grinding should be performed with crankshaft rotation opposite to actual engine rotation. While polishing should be performed with the crankshaft rotation in the same direction as engine rotation.

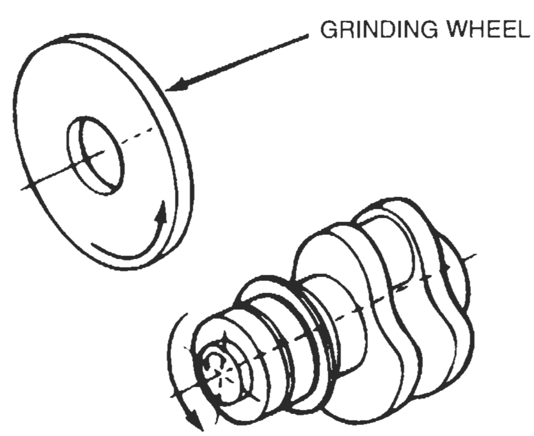


Figure 1–376 Crankshaft Grinding Rotation

2. Crankshaft polishing should be performed with the crankshaft rotation in the same direction as engine rotation.
3. All connecting rod journal fillets must have a 5.75 mm (.226 in.) for 23511363 crank, and 3.75 mm (.148 in.) for crank 23515595 radius between the crank cheek and the journal.
4. All main journal fillets must have a 3.75 mm (.148 in.) radius between the crank cheek and the journal.
5. No journal may have any sharp grind marks. The fillet must blend smoothly into the journal and the crank cheek and must be free of scratches.

6. The radius may be checked with a fillet gage. See Figure 1–377.

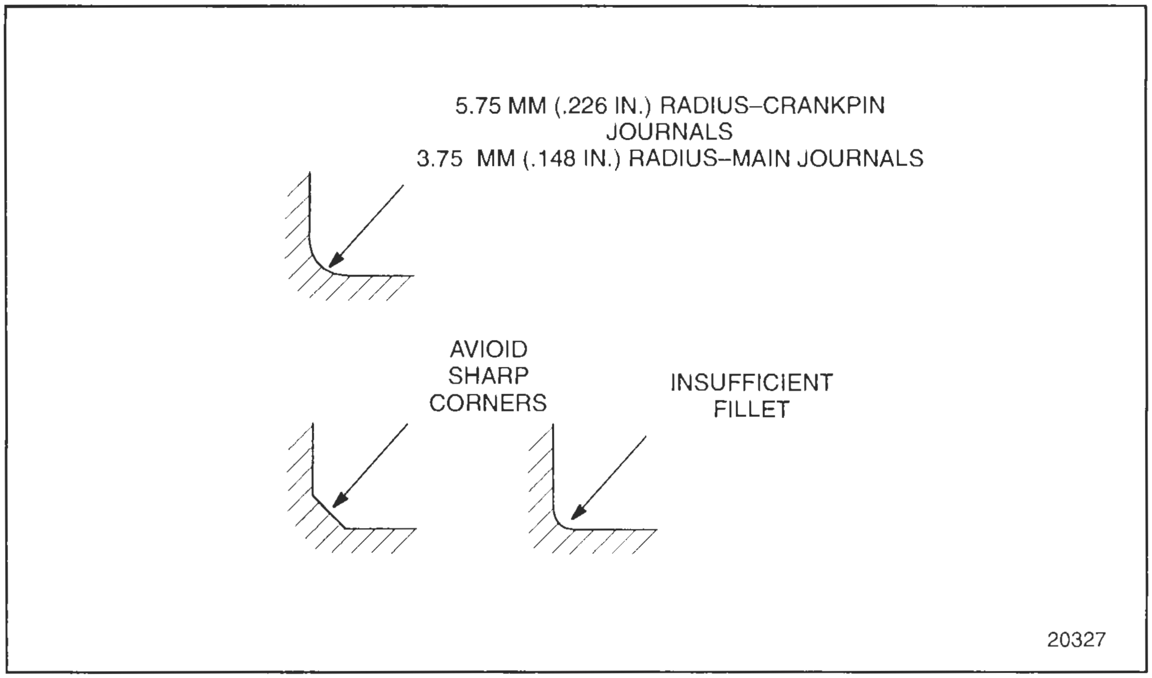


Figure 1–377 Crankshaft Journal Fillets

7. Lobing and Chatter: The No. of lobes around the journal circumference, times the average peak to valley lobe height in micrometers, shall not exceed 42 micrometers. Peak to valley excursions exceeding 1.0 micrometers shall be considered lobing or chatter.
8. Excursions can be measured on a circular chart of the circumferential profile.

Grinding Connecting Rod Journals (Pins)

Perform the following steps for grinding connecting rod journals:

1. Grind the pin O.D. surface to the specified undersize. The undersize conditions are 0.250 mm, 0.500 mm or 0.750 mm (approximately .010 in., .020 in. or .030 in.) undersize.
2. ALL connecting rod journals must be ground to the same undersize condition.
3. Journal taper on a radial basis shall not exceed 0.008 mm (.0003 in.) overall, or exceed 0.004 mm (.00016 in.) on half-length.

NOTE:
Avoid localized heating, which often produces grinding cracks. Cool the crankshaft generously with coolant while grinding. Do not crowd the grinding wheel into the work.

4. Grind sidewalls wide enough to clean up the basic face surface, not to exceed pin width allowable. See Figure 1–375.
5. If there are deep interruptions, gouges or nicks that do not extend into fillets, smooth the edges with 120 grit emery cloth.

Grinding Main Bearing Journals

Perform the following steps for grinding main bearing journals:

1. Grind the main bearing O.D. surface to the specified undersize. The undersize conditions are 0.250, 0.500 or 0.750 mm (approximately .010, .020, or .030 in.) undersize.

NOTE:
Avoid localized heating, which often produces grinding cracks. Cool the crankshaft generously with coolant while grinding. Do not crowd the grinding wheel into the work.

2. ALL main bearing journals must be ground to the same undersize conditions.
3. Journal taper on a radial basis shall not exceed 0.012 (.0005 in.) overall or exceed 0.006 mm (.00024 in.) on half-length.

Other Machining Operations:

Perform the following steps for other machining operations:

1. Examine the thrust wall (No. 4 Main Bearing):
   [a] If the thrust wall surface is scored, scratched or groove worn, the thrust wall must be "bump ground."
   [b] The maximum run out of the thrust wall is 0.038 mm (.0015 in.) TIR.
   [c] If wear is 0.0508 mm (.002 in.) or more, regrind to restore flatness to the thrust wall. See Figure 1-378.

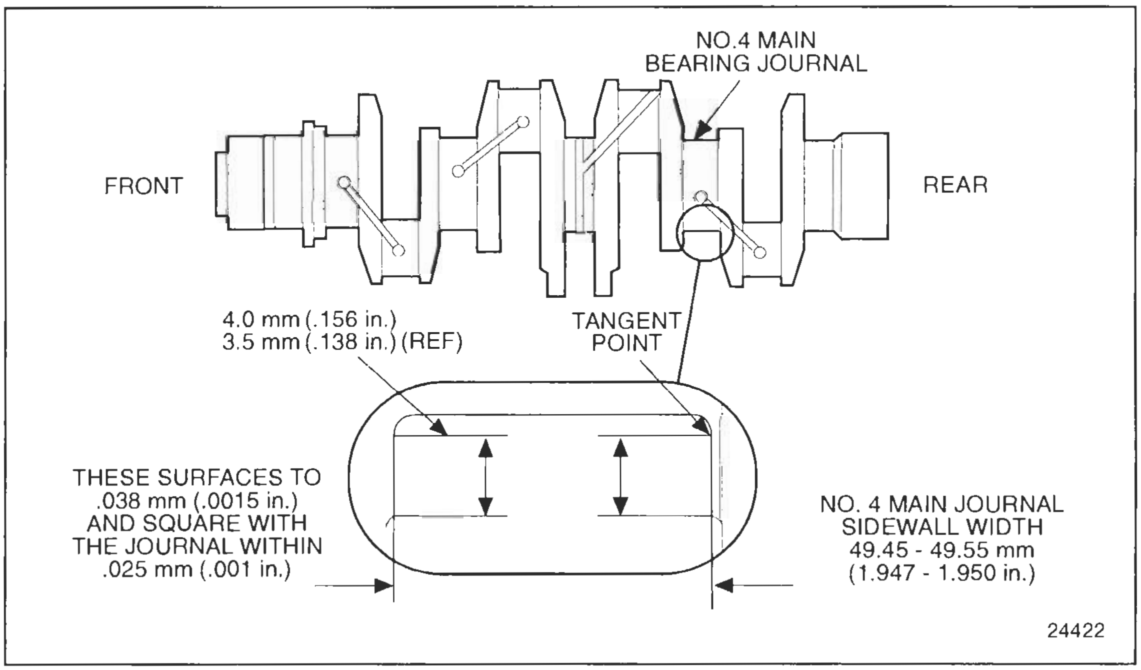


Figure 1-378 No. 4 Main Journal Thrust Wall Dimensions

   [d] An oversize thrust wall is to be "bump ground" in multiples of 0.127 mm (.005 in.), with a maximum of 0.250 mm (.010 in.) to be removed from each side. Record oversize for installations.

NOTE:
Avoid localized heating, which often produces grinding cracks. Cool the crankshaft generously with coolant while grinding. Do not crowd the grinding wheel into the work.

2. Chamfer all oil holes to remove grinding burrs to the limit shown on illustrations. See Figure 1-379. See Figure 1-380. See Figure 1-381.

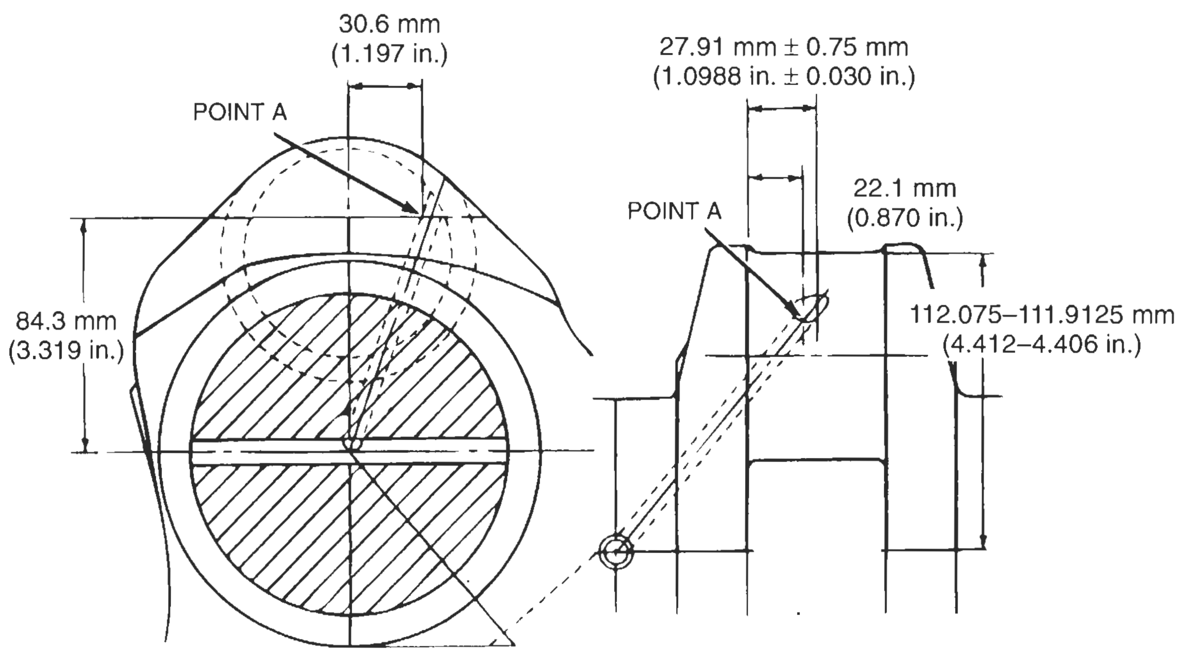


Figure 1-379 Oil Hole Specifications – Connecting Rod Journals – Crankshaft (160 mm stroke)

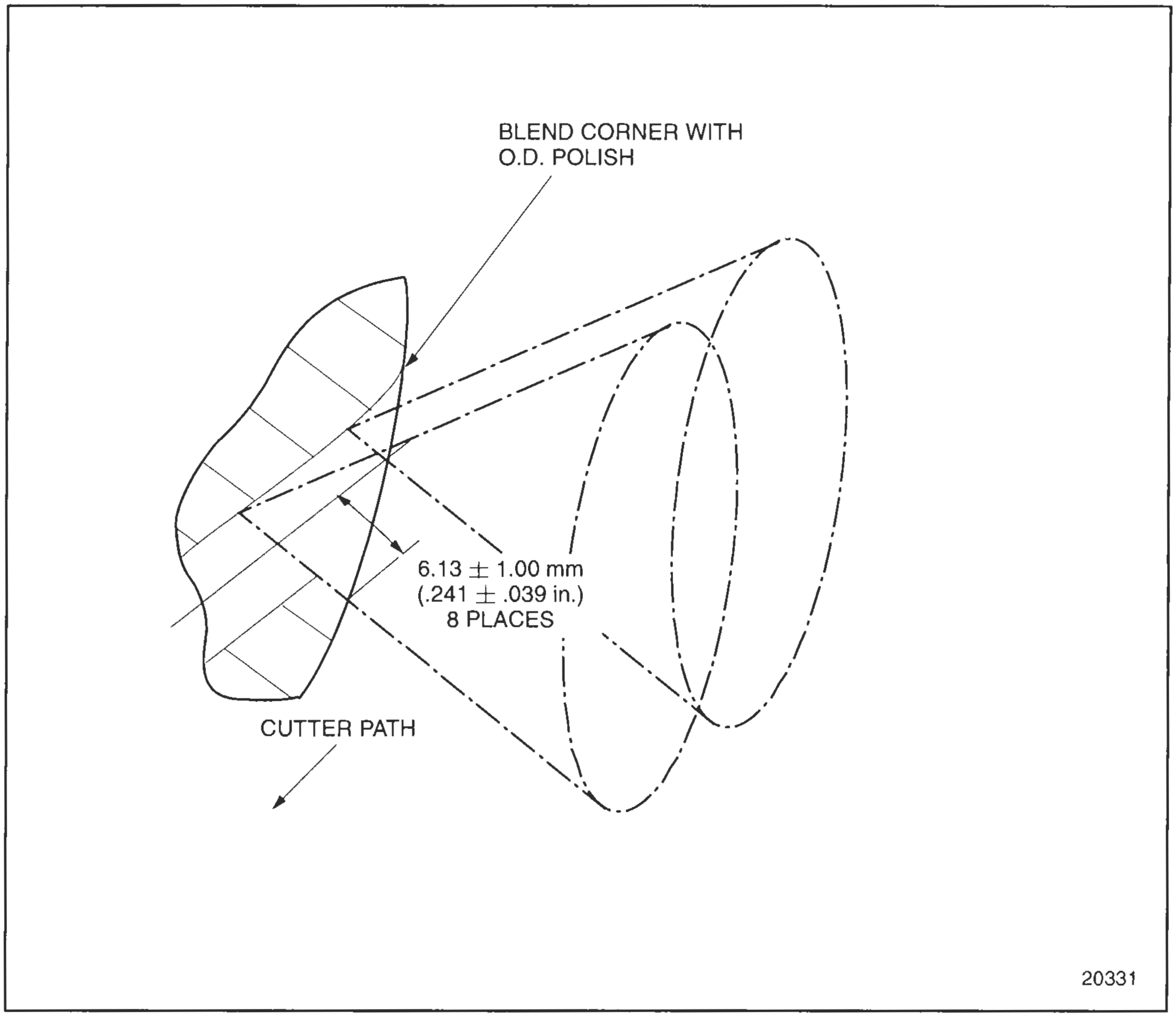


Figure 1–380 Connecting Rod Journal Oil Hole Chamfer Limits

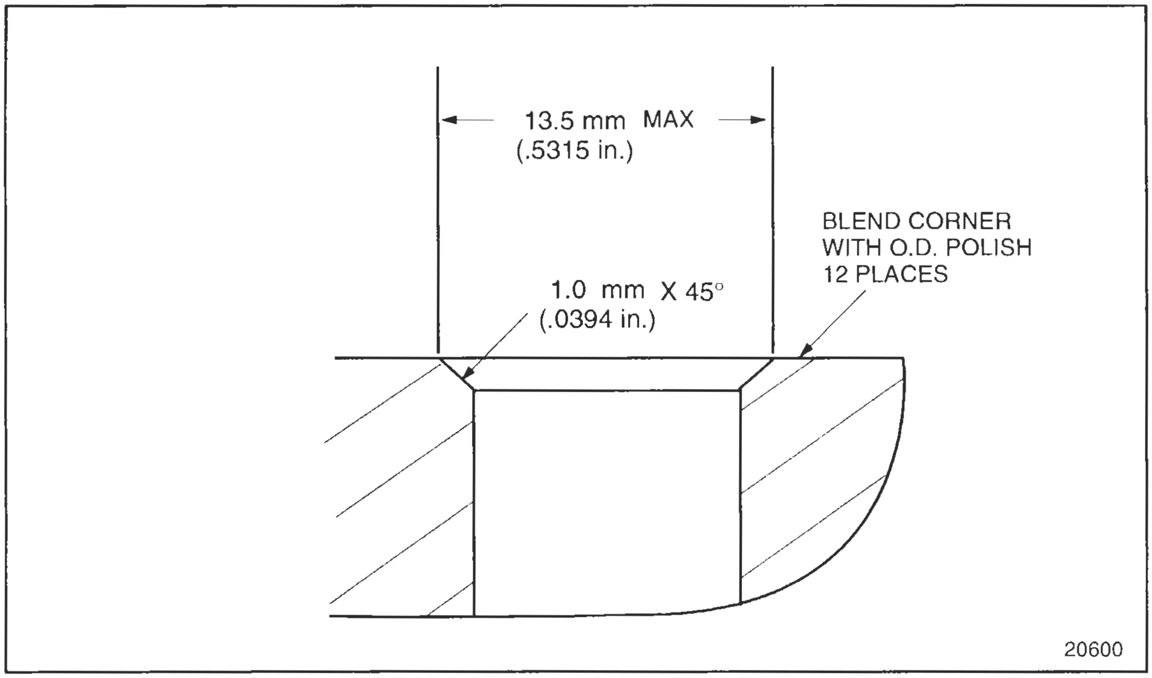


Figure 1–381 Main Journal Oil Hole Chamfer Limits

3. Repair the flywheel and pulley contact faces of the crankshaft to clean up the surface of any nicks, gouges or raised metal. The crankshaft face must be 0.013 mm (.0005 in.) convex to 0.030 mm (.001 in.) concave.

After–grinding Inspection

Perform the following steps for after grinding:

1. Inspect the crankshaft by the magnetic particle method after grinding has been completed to determine whether the grinding operation has produced cracks.
2. Retap and check all internal threads with plug gages to determine acceptability. If necessary, Heli–coil pulley and flywheel flange bolt holes with the following restrictions: Heli–coil 2 holes max. per crankshaft end (front or rear). Heli–coil of two adjacent holes at rear (forward end) is not permitted.
3. Demagnetize the crankshaft.
4. Clean the crankshaft and oil passages thoroughly with clean fuel oil.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

5. Dry the crankshaft with compressed air.

GLOSSARY

The following glossary terms support the Series 50 Engines.

Glossary Terms

AA – ARITHMETICAL AVERAGE: The average total sum of the heights and depths of the ridges and valleys above and below the mean reference line. Limits for journal surfaces are 0.3 µn (12 AA).

AXIAL PROFILE: The deviation of the journal surface from a reference line. Total peak to valley variation per full length of journal.

AXIAL PROFILE SLOPE: The amount of variation tolerable from the mean reference line of the journal in a particular distance (example: 0.0025 mm [.0001 in.] deviation/2.54 mm [.100 in.] length maximum). This specification indicates that any deviation in excess of 0.0025 mm (.0001 in.) inside a 2.54 mm (.100 in.) length is not acceptable.

GOULD 1200: Surfanalyzer 1200 surface texture measuring system is used to determine surface parameters such as profile, roundness and waviness. A diamond stylus having a radius of 0.0025–0.013 mm (.0001–.0005 in.) is moved at a constant speed over the surface. Vertical displacements of this stylus are converted into a voltage signal through a linear variable differential transformer.

OIL HOLE WASHOUT: The localized removal of material below the reference surface of an idealized round and straight journal at the trailing edge of the oil hole. This condition is the result of excessive polishing with a soft black apparatus (nut cracker, soft show, rawhide) with lapping paper or cloth in an attempt to improve the surface finish.

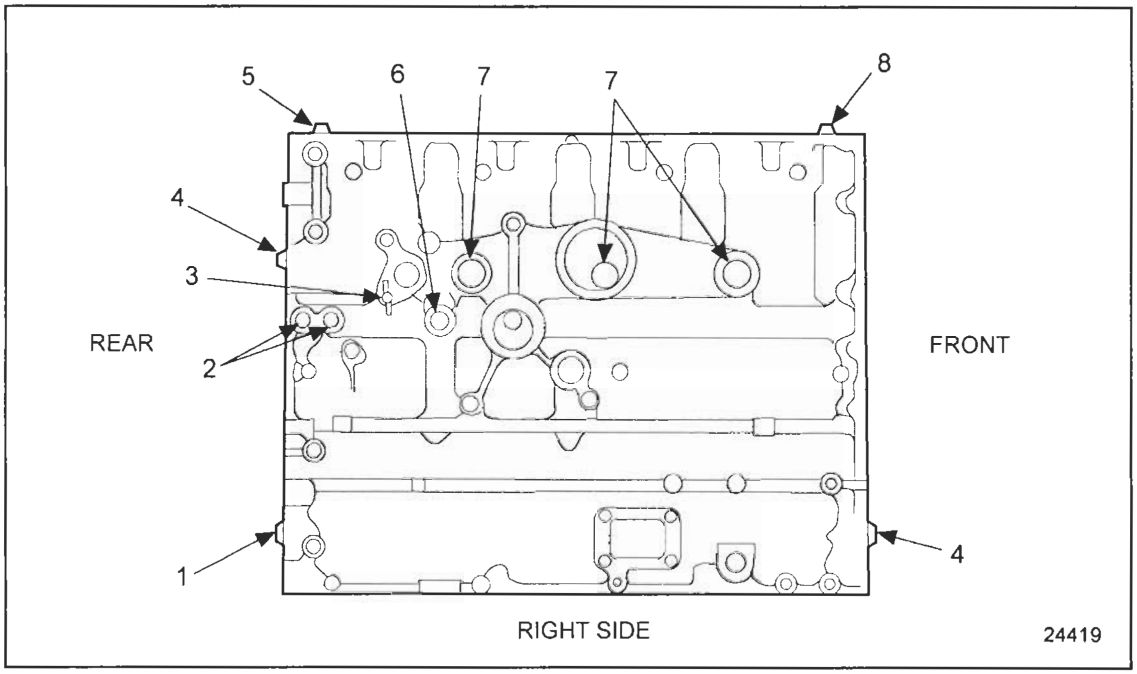
A depression (washout) extending beyond the oil hole blend out ellipse reduces the effective bearing area appreciably. This type of polishing is not recommended.

PIN and CRANKPIN: The cylindrical piece to which the connecting rod is attached.

RADIAL CHATTER: This term relates to surface irregularities which are of greater magnitude or spacing than those indicated by the term roughness. Chatter might be the result of vibration or deflection of a cutting tool, of some part of the machine, or the the work itself.

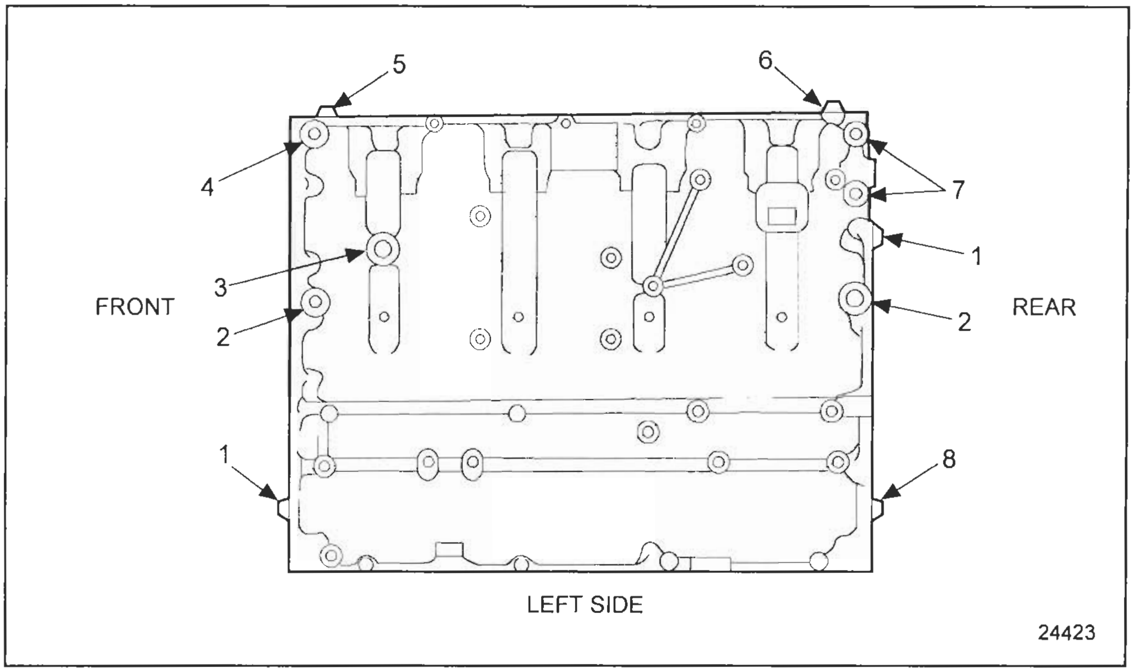
ENGINE PLUG AND DOWEL CHARTS

The following graphics, see Figure 1–382, see Figure 1–383, see Figure 1–384, see Figure 1–385, see Figure 1–386, see Figure 1–387, see Figure 1–388, and see Figure 1–389, support the Series 50 Engines plugs and dowels configurations.



1. 8929015 Dowel (Round)
2. 8922327 1/4 in. Pipe Plug (4 places). Tighten to 19–24 N·m (14 –18 lb·ft) Torque.
3. 8924140 Draincock
4. 8929022 Dowel (Diamond) (Places)
5. 8929153 Dowel (Diamond)
6. 8929594 3/8 in. Pipe Plug (2 places). Tighten to 24–31 N·m (18 – 23 lb·ft) Torque.
7. Cup Plug (3 places)
8. 8929152 Dowel (Round)

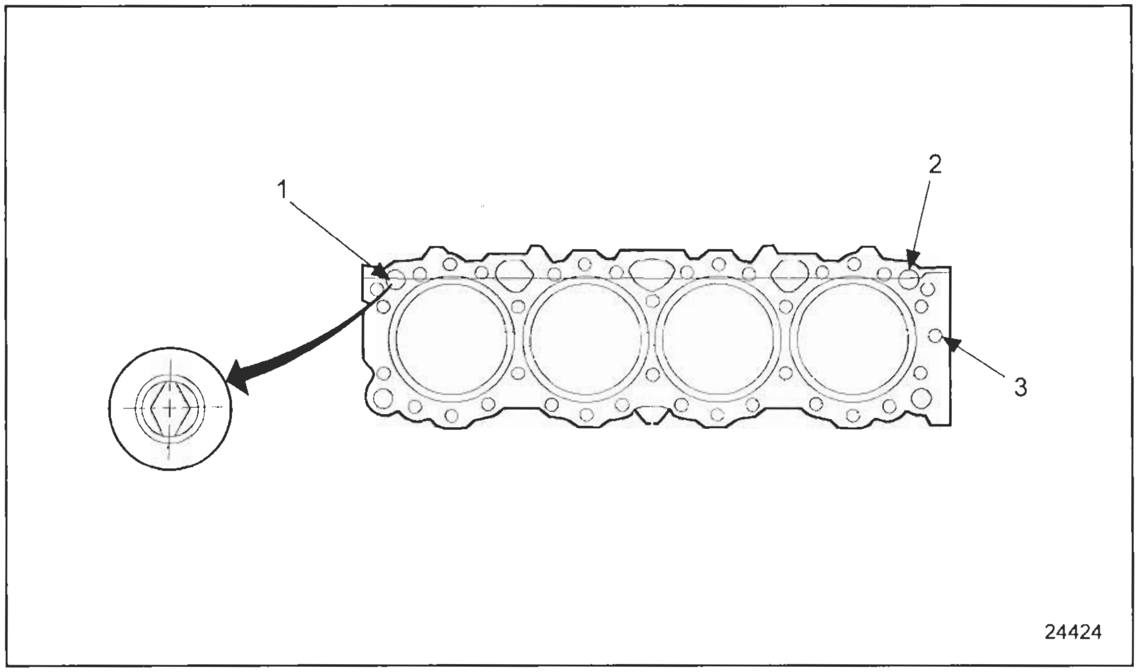
Figure 1–382 Right Side View



1. 8929022 Dowel (Diamond) (2 places)
2. 8923916 3/8 in. Pipe Plug (2 places). Tighten to 24–31 N·m (18–23 lb·ft) Torque.
3. 8923916 1/2 in. Pipe Plug (1 place) tighten to 31–39 N·m (23–29 lb·ft) Torque.
4. 8922327 1/4 in. Pipe Plug (4 places). Tighten to 19–24 N·m (14–18 lb·ft) Torque.
5. 8929152 Dowel (Round)
6. 8929153 Dowel (Diamond)
7. 8922327 1/4 in. Pipe Plug (2 places).*
8. 8929015 Dowel (Round)

*Required for pressure testing only.

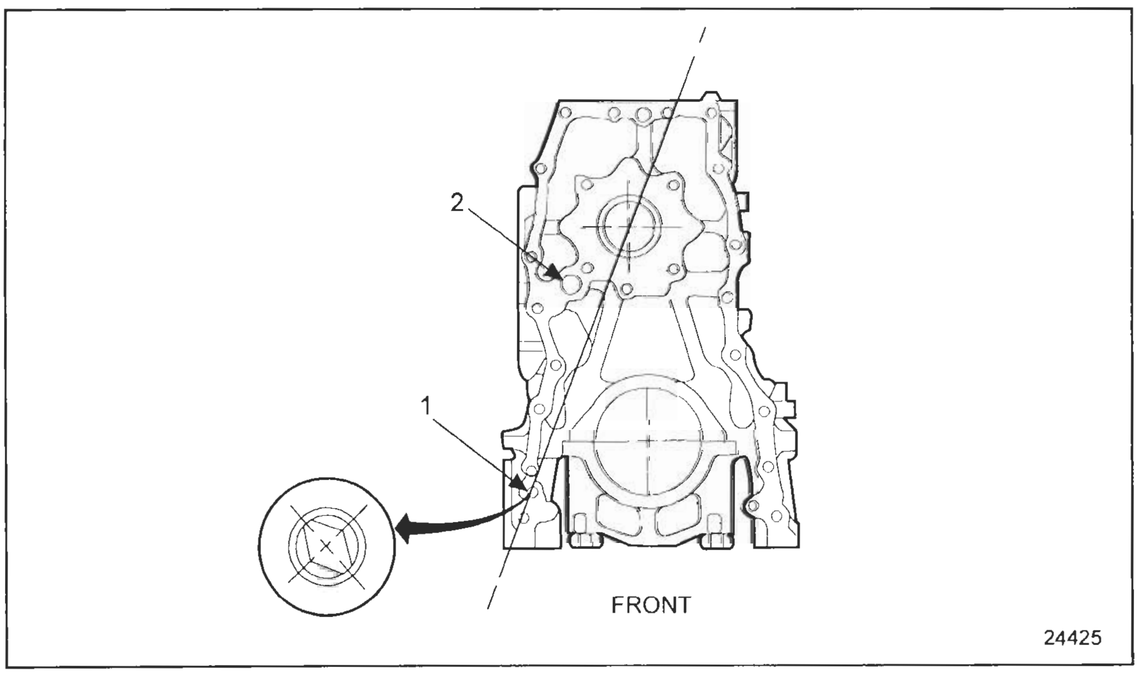
Figure 1–383 Left Side View



1. 8929153 Dowel (Diamond)
2. 8929152 Dowel (Round)
3. 5151272 Plug*

* Install flush to 1.0 mm (0.040 in.) below surface.

Figure 1–384 Cylinder Head Deck



1. 8929022 Dowel (Round)
2. 8929015 Dowel (Round)

Figure 1–385 Front View

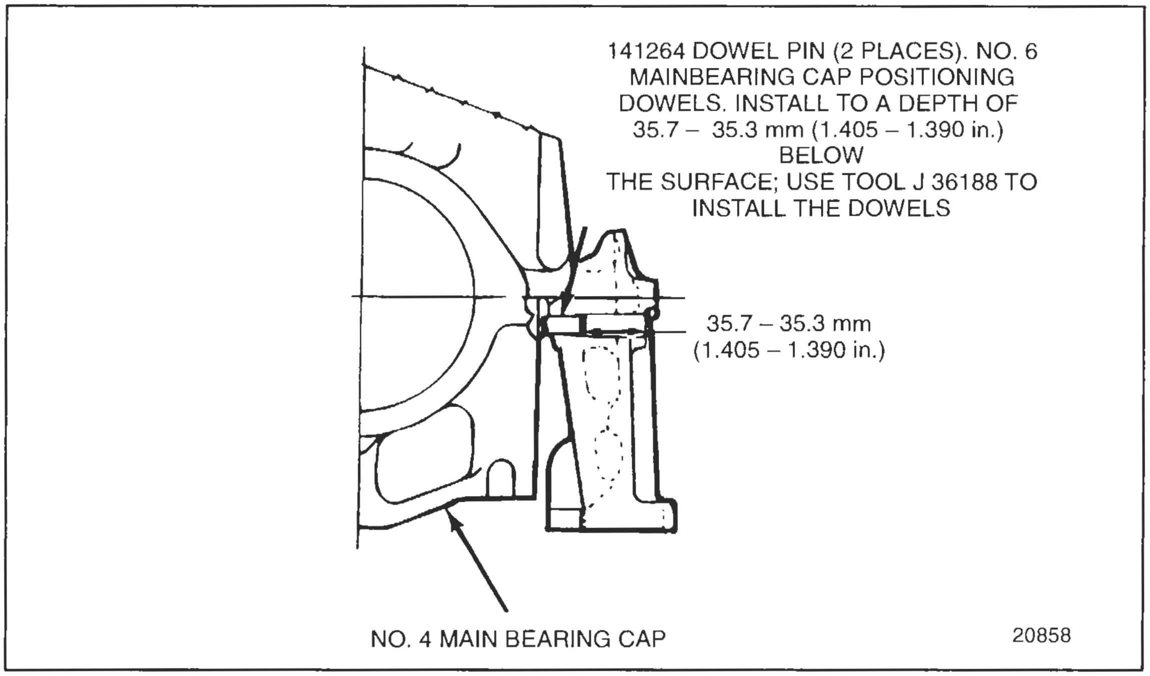
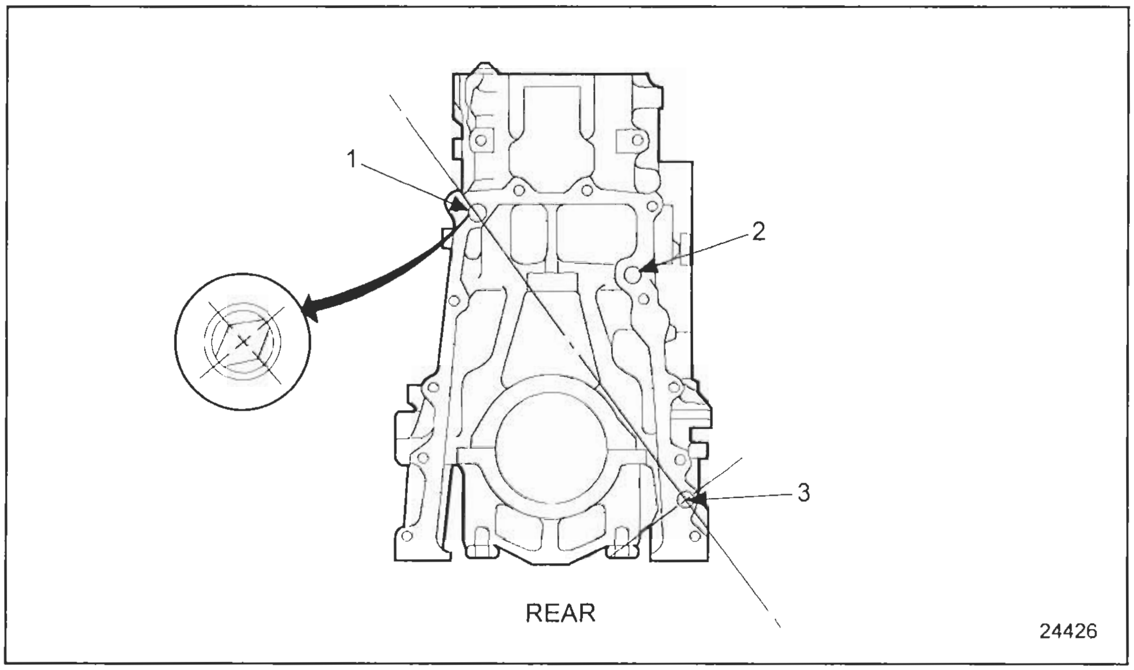
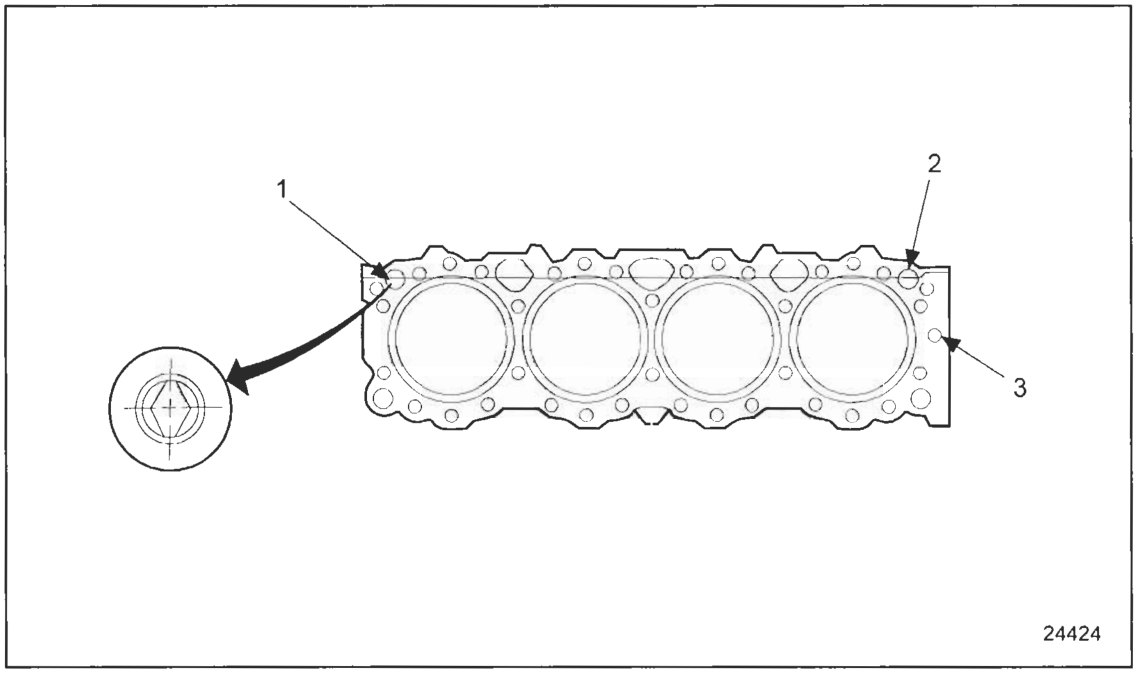


Figure 1–386 No. 4 Main Bearing Cap



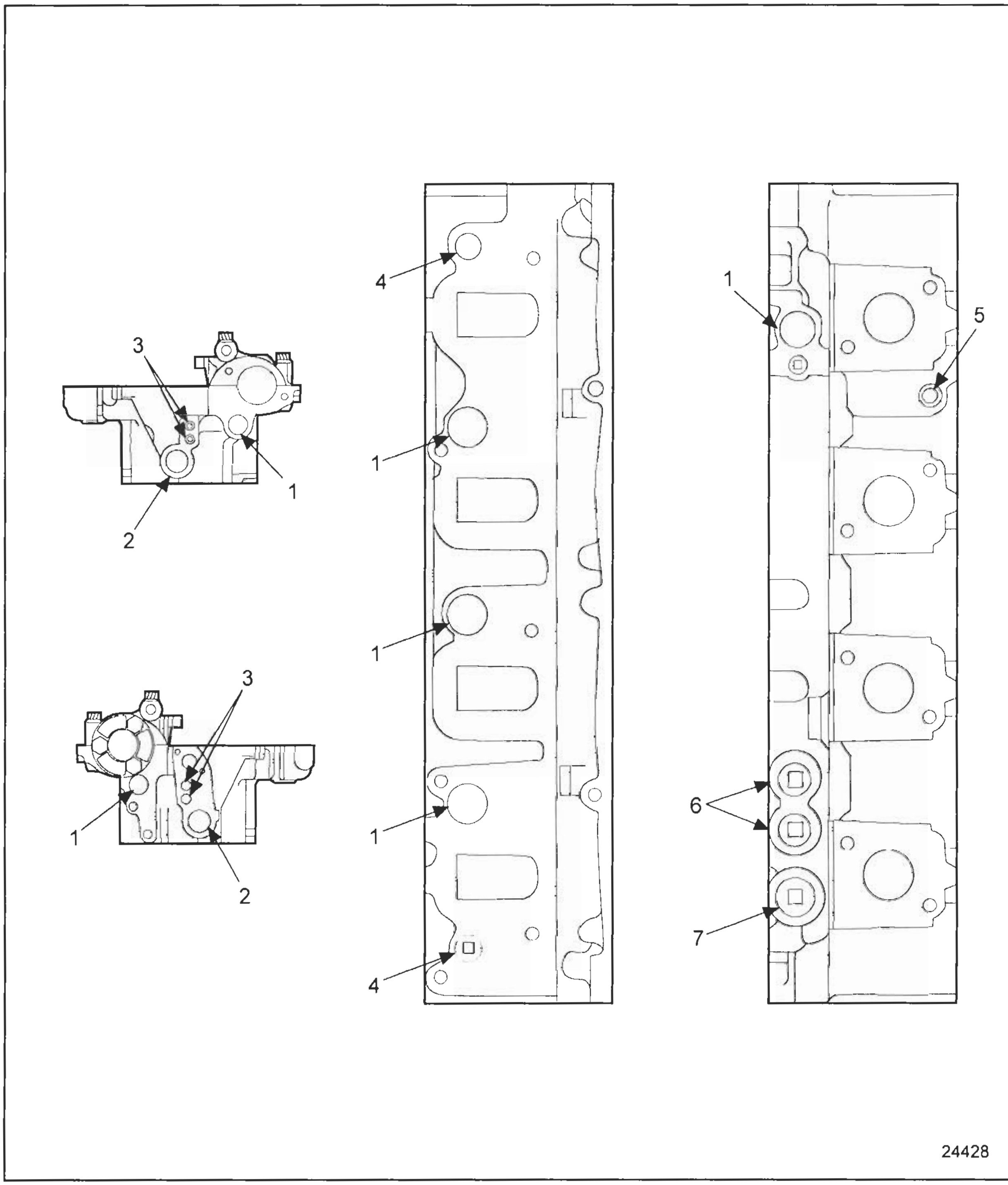
1. 8929022 Dowel (Round)
2. 5139988 Cup Plug (2 places)
3. 8929015 Dowel (Round)

Figure 1–387 Rear View



1. 5138638 Dowel (Hollow) (5 places). Install to a height of 5.0mm ±0.5 mm (0.199 in. ±0.010 in.). Bearing Cap.
2. 5143033 Dowel (Diamond) (3 places). Install to a height of 6.1 mm ±0.5 mm (0.240 in. ±0.010 in.).

Figure 1–388 Cylinder Head Dowel Chart



1. 5109157 Cup Plug (6 places)
2. 5139991 Cup Plug (2 places).
3. 23513197 Square Head Pipe Plug. Front and Rear.
4. 23511572 1/2 in. Pipe Plug (2 places). Tighten to 31–39 N·m (23–29 lb·ft) Torque.
5. 89269991 Fuse Plug. Tighten to 19–24 N·m (14–18 lb·ft) Torque.
6. 23511573 3/4 in. Pipe Plug (2 places). Tighten to 45–56 N·m (33–41 lb·ft) Torque.
7. 23511574 1 in. Pipe Plug (1 place). Tighten to 19–24 N·m (14–18 lb·ft) Torque.

Figure 1–389 Cylinder Head Cup and Pipe Plug and Dowel Chart

SPECIFICATIONS

Specifications, clearances and wear limits are listed below. It should be specifically noted that the clearances apply only when all new parts are used at the point where the various specifications apply. This also applies to references within the text of the manual. The column entitled "Limits," in the following Tables, lists the amount of wear or increase of clearance which can be tolerated in used engine parts and still ensure satisfactory performance. It should be emphasized that the values given as "Limits" must be qualified by the judgment of personnel responsible for installing new parts. These wear limits are, in general, listed only for the parts more frequently replaced in engine overhaul work. For additional information, refer to the text.

Table of Specifications, New Clearances, and Wear Limits

These limits also apply to oversize and undersize parts.

Refer to the following Tables to obtain specifications, new clearances, and wear limits for the Series 50 Engines:

1. Cylinder block is listed in Table 1–10.
2. Cylinder liner is listed in Table 1–11.
3. Cross–head piston and piston rings is listed in Table 1–12.
4. Piston pin is listed in Table 1–13.
5. Crankshaft is listed in Table 1–14.
6. Connecting rod bearing is listed in Table 1–15.
7. Main bearing is listed in Table 1–16.
8. Camshaft is listed in Table 1–17.
9. Camshaft bearing is listed in Table 1–18.
10. Camshaft drive gear is listed in Table 1–19.
11. Idler gear is listed in Table 1–20.
12. Crankshaft timing gear is listed in Table 1–21.
13. Bull gear is listed in Table 1–22.
14. Cylinder head is listed in Table 1–23.
15. Intake valve seat insert is listed in Table 1–24.
16. Exhaust valve seat insert is listed in Table 1–25.
17. Intake valves is listed in Table 1–26.
18. Exhaust valves is listed in Table 1–27.
19. Valve guides is listed in Table 1–28.
20. Rocker arms and shaft is listed in Table 1–29.
21. Cam follower roller is listed in Table 1–30.

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Cylinder Block	–	–	–
Block Bore: Diameter– 15.0 mm (.60 in.) form top of block	149.050 mm (5.868 in.)	149.120 mm (5.871 in.)	0.070 mm (.003 in.)
Diameter–235.0 mm (9.25 in.) from top of block	146.050 mm (5.750 in.)	146.120 mm (5.753 in.)	0.070 mm (.003 in.)
Diameter–270.0 mm (10.63 in.) from top of block	146.050 mm (5.750 in.)	146.120 mm (5.753 in.)	0.070 mm (.003 in.)
Out–of–round	–	–	0.0254 mm (.001 in.)
Taper (lower bore)	–	–	0.0254 mm (.001 in.)
Cylinder Liner Counterbore:	–	–	–
Diameter	157.15 mm (6.186 in.)	157.25 mm (6.191 in.)	–
Depth *	8.9246 mm (.3514 in.)	8.9746 mm (.3533 in.)	–
Main Bearing Bore:	–	–	–
Inside diameter (vertical axis)	133.00 mm (5.236 in.)	133.025 mm (5.237 in.)	–
Top Surface of Block:	–	–	–
Center of main bearing bore to top of block	436.50 mm (17.1850 in.)	436.62 mm (17.1897 in.)	–
Flatness (transverse)	–	–	0.076 mm (.003 in.)
Flatness (longitudinal)	–	–	0.120 mm (.005 in.)

*The bottom of the counterbore must not vary in depth more than 0.04 mm (.0015 in.). No two adjacent counterbores can vary in depth more than 0.025 mm (.001 in.) when gaged longitudinally.

Table 1–10 Cylinder Block

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Outside Diameter (below flange)	148.95 mm (5.864 in.)	149.00 mm (5.866 in.)	–
Outside Diameter (below crevice seal groove)	145.985 mm (5.747 in.)	146.035 mm (5.749 in.)	–
Outside Diameter (between "D" ring grooves)	145.985 mm (5.747 in.)	146.035 mm (5.749 in.)	–
Flange Thickness	8.960 mm (.3527 in.)	9.00 mm (.3543 in.)	–
Inside Diameter	130.00 mm (5.118 in.)	130.05 mm (5.120 in.)	–
Out–of–Round (inside diameter)	–	–	0.025 mm (.001 in.)
Taper	–	–	0.025 mm (.001 in.)
Height of Flange ABOVE Block	0.000 mm (.000 in.)	0.076 mm (.003 in.)	–
Variation in Height between Adjacent Liners	–	–	0.05 mm (.002 in.)

Table 1–11 Cylinder Liner

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
At top (above firing ring)	128.64 mm (5.064 in.)	128.84 mm (5.072 in.)	–
Below (2nd) compression ring	129.775 mm (5.1093 in.)	129.825 mm (5.112 in.)	–
Compression Rings	–	–	–
Gap (2.5 mm chrome fire ring)	0.40 mm (.016 in.)	0.87 mm (.034 in.)	–
Gap (3.5 mm plasma fire ring) (High sulfur fuel export engines)	0.51 mm (.020 in.)	0.87 mm (.034 in.)	–
Gap (No. 2 compression ring)	0.80 mm (.031 in.)	1.31 mm (.051 in.)	–
Clearance ring–to–groove:	–	–	–
Top (keystone fire ring)	must be checked with Piston Ring Land Gage J 35884–A	–	–
No. 2 (keystone compression ring)	must be checked with Piston Ring Land Gage J 38689–A	–	–
Oil Control Rings	–	–	–
Gap	0.40 mm (.016 in.)	0.81 mm (.032 in.)	–
Clearance	0.03 mm (.001 in.)	0.11 mm (.004 in.)	–
Piston Pin Bore in Dome (3–piece bushing) *	51.000 mm (2.0078 in.)	51.025 mm (2.0088 in.)	–
Piston Skirt to Liner Clearance (thrust faces)	0.047 mm (.0020 in.)	0.184 mm (.0072 in.)	–

* Both ends must be measured on vertical and horizontal planes

Table 1–12 Cross–head Piston and Piston Rings

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Piston Pin Diameter	44.99 mm (1.7712 in.)	45.00 mm (1.7716 in.)	44.96 mm (1.770 in.)

Table 1–13 Piston Pin

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Journal Diameter (main bearing)	124.975 mm (4.920 in.)	125.000 mm (4.921 in.)	–
Journal Diameter (connecting rod bearing)	84.975 mm (3.345 in.)	85.000 mm (3.346 in.)	–
Journal Out–of–Round (ROD)	–	–	0.008 mm (.0003 in.)
Journal Out–of–Round (MAIN)	–	–	0.0127 mm (.0005 in.)
Journal Taper:Main Bearing	–	–	0.0127 mm (.0005 in.)
Connecting Rod (full length)	–	–	0.008 mm (.0003 in.)
Connecting Rod (half length)	–	–	0.004 mm (.00016 in.)
Run–out on Journals– Total Indicator Reading (mounted on numbers 1 and 7 Journals):At Journals No. 2 and 6 *	–	–	0.075 mm (.003 in.)
At Journals No. 3 and 5	–	–	0.130 mm (.005 in.)
At Journal No. 3	–	–	0.152 mm (.006 in.)
No. 4 Main Bearing Journal Thrust Width	49.45 mm (1.947 in.)	49.55 mm (1.950 in.)	–
Thrust washer Thickness	3.48 mm (.137 in.)	3.56 mm (.140 in.)	–
End Play (end thrust clearance)	0.097 mm (.0039 in.)	0.419 mm (.0165 in.)	–

* Runout tolerance given for guidance when regrinding crankshaft. When the runout on adjacent journals is in the opposite direction, the sum must not exceed 0.076 mm (.003 in.) total indicator reading. When the runout on adjacent journals is in the same direction, the difference must not exceed 0.076 (.003 in.) total indicator reading.

Table 1–14 Crankshaft

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Bearing–to–Journal Clearance	0.040 mm (.0016 in.)	0.116 mm (.005 in.)	0.151 mm (.006 in.)
Bearing Thickness 90° from Parting Line	3.111 mm (.1224 in.)	3.125 mm (.1230 in.)	3.086 mm (.1215 in.)

Table 1–15 Connecting Rod Bearing

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Bearing–to–Journal Clearance	0.040 mm (.0016 in.)	0.126 mm (.005 in.)	0.151 mm (.006 in.)
Bearing Thickness 90° from Parting Line	3.962 mm (.1559 in.)	3.980 mm (.1566 in.)	3.937 mm (.1550 in.)

Table 1–16 Main Bearing

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Diameter (bearing journals)	64.974 mm (2.558 in.)	65.000 mm (2.5559 in.)	–
Runout at Center Bearing (when mounted on end bearings should not exceed)	–	–	0.050 mm (.002 in.)
End Thrust	0.076 mm (.003 in.)	0.381 mm (.015 in.)	–

Table 1–17 Camshaft

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Bearing–to–Journal Clearance	0.090 mm (.0035 in.)	0.166 mm (.0065 in.)	0.191 mm (.0075 in.)
Bearing Thickness (90° from Parting Line)	1.942 mm (.0764 in.)	1.955 mm (.0769 in.)	–

Table 1–18 Camshaft Bearing

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Inside Diameter:	–	–	–
Camshaft Drive Gear	52.00 mm (2.0472 in.)	52.0 mm (2.0484 in.)	–
Outside Diameter:	–	–	–
Camshaft Hub	52.10 mm (2.0511 in.)	52.03 mm (2.0523 in.)	–
* Interference (gear–to–hub)	0.07 mm (0.0027 in.)	0.13 mm (.0051 in.)	–
Backlash (cam gear–to–adjustable idler)	0.051 mm (.002 in.)	0.229 mm (.009 in.)	0.305 mm (.012 in.)

*A minimum force of 20.0 kN (4500 lb) must be obtained when pressing the camshaft drive gear to the drive gear hub.

Table 1–19 Camshaft Drive Gear

Engine Part (standard Size, New)	Minimum	Maximum	Limits
Backlash (adjacent idler–to–cam idler	0.051 mm (.002 in.)	0.229 mm (.009 in.)	0.305 mm (.012 in.)

Table 1–20 Idler Gear

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Inside Diameter:	–	–	–
8.5 Liter Engine	133.562 mm (5.2583 in.)	133.600 mm (5.2598 in.)	–
* Interference (gear–to–crankshaft)	0.100 mm (.003 in.)	0.108 mm (press) (.004 in.) (press)	–
Backlash:	–	–	–
Crank Gear–to–Bull Gear	0.051 mm (.002 in.)	0.229 mm (.009 in.)	0.305 mm (.012 in.)
Crankshaft Gear–to–Oil Pump Drive Gear	0.051 mm (.002 in.)	0.229 mm (.009 in.)	0.035 mm (.012 in.)

*A minimum force of 30 kN (6750 lb) must be obtained when pressing the crankshaft timing gear on the crankshaft.

Table 1–21 Crankshaft Timing Gear

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Backlash (Bull Gear–to–Water Pump, Accessory, Fuel Pump or Air Compressor Drive Gears)	0.051 mm (.002 in.)	0.229 mm (.009 in.)	0.3050 mm (.012 in.)

Table 1–22 Bull Gear

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Flatness (transverse)	–	–	0.076 mm (.003 in.)
Flatness (longitudinal)	–	–	0.120 mm (.005 in.)
Distance between Rail and firedeck (new)	164.85 mm (6.490 in.)	165.15 mm (6.501 in.)	–
Distance between Rail and firedeck (resurfaced)	164.08 mm (6.460 in.)	–	0.762 mm (.030 in.)
Valve Insert Counterbore:	–	–	–
Intake Valve:	–	–	–
Diameter	46.12 mm (1.8157 in.)	46.15 mm (1.8169 in.)	–
Depth	11.46 mm (.4511 in.)	11.76 mm (.4629 in.)	–
Valve Insert Counterbore:	–	–	–
Exhaust Valve:	–	–	–
Diameter	41.26 mm (1.6244 in.)	41.29 mm (1.6255 in.)	–
Depth	10.70 mm (.4212 in.)	11.00 mm (.4330 in.)	–

Table 1–23 Cylinder Head

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Outside Diameter	46.20 mm (1.8188 in.)	46.22 mm (1.8196 in.)	–
Seat Width	0.48 mm (.019 in.)	2.14 mm (.084 in.)	–
Valve Seat Runout	–	–	0.05 mm (.002 in.)
Standard Seat Thickness	7.155 mm (.2187 in.)	7.256 mm (.2857 in.)	–

Table 1–24 Intake Valve Seat Inserts

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Outside Diameter	41.34 mm (1.627 in.)	41.36 mm (1.628 in.)	–
Seat Width	0.67 mm (.026 in.)	2.66 mm (.105 in.)	–
Valve Seat Runout	–	–	0.05 mm (.002 in.)
Standard Valve Seat Thickness	6.261 mm (.2465 in.)	6.362 mm (.2505 in.)	–

Table 1–25 Exhaust Valve Seat Inserts

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Stem Diameter	8.679 mm (.3416 in.)	8.699 mm (.3424 in.)	–
Valve Head–to–Cylinder Head 30° (recess)	1.4 mm (.055 in.)	1.8 mm (.071 in.)	–

Table 1–26 Intake Valves

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Stem Diameter	8.679 mm (.3416 in.)	8.699 mm (.3424 in.)	–
Valve Head–to–Cylinder Head 30° (recess)	1.4 mm (.055 in.)	1.8 mm (.071 in.)	–

Table 1–27 Exhaust Valves

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Height Above Cylinder Head	37.5 mm (1.476 in.)	38.0 mm (1.496 in.)	—
Diameter (inside)	8.759 mm (.345 in.)	8.827 mm (.348 in.)	—
Clearance (valve–to–guide, maximum)	—	—	0.148 mm (.006 in.)

Table 1–28 Valve Guides

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Rocker Shaft Diameter	35.993 mm (1.417 in.)	36.007 mm (1.418 in.)	35.943 mm (1.415 in.)
Steel Rocker Arm Bushing Diameter(inside)	36.025 mm (1.418 in.)	36.110 mm (1.422 in.)	36.200 mm (1.425 in.)
Clearance (shaft to bushing) (maximum): Bronze Bushing	–	–	0.482 mm (.019 in.)
Steel Bushing	–	–	0.257 mm (.010 in.)

Table 1–29 Rocker Arms and Shafts

Engine Part (Standard Size, New)	Minimum	Maximum	Limits
Diameter	37.95 mm (1.494 in.)	38.05 mm (1.498 in.)	–
Rollers and Pins:	–	–	–
Clearance (pin–to–bushing) (maximum) (horizontal)	–	–	0.08 mm (.003 in.)
Side Clearance (roller–to–follower) (maximum)	–	–	0.40 mm (.015 in.)

Table 1–30 Cam Follower Roller

Exceptions to Standard Fastener Torque Specifications

Listed in Table 1-31 are exceptions to standard fastener torque specifications supporting the Series 50 Engines.

SECTION	FASTENER	SIZE	N·m	(lb·ft)
Refer to section 1.2	Bolt, Cylinder Head (torque twice)	M16 X 2.0	250–285	(185–210)
Refer to section 1.2	Bolt, Injector. Harness Mounting Flange	M8 X 1.25	10–15	(7–11)
Refer to section 1.6.4	Bolt, Rocker Cover–to–Cylinder Head	3/8–16	22–25	(16–18)
Refer to section 1.7	Bolt, Main Bearing Cap	M20 X 2.5	470–530	(347–391)
Refer to section 1.11	Plug, Gear Case Adj. Idler Oil Hole	5/16–24	15–20	(11–15)
Refer to section 1.10.3	Bolt, Front Pulley	9/16–18	182–210	(134–155)
Refer to section 1.14.3	Bolt, Flywheel	9/16–18	68 (+120°)	(50) (+120°)
Refer to section 1.18.4	Bolt, Conn. Rod–to–Piston Pin	M14 X 1.5	157 ±6.8	(115 ±5)
Refer to section 1.18.2	Nut, Connecting Rod	M14 X 1.5	160–185	(118–137)
Refer to section 1.21.2	Bolt, Camshaft Bearing Cap	M12 X 1.75	101–116	(75–86)
Refer to section 1.21.2.1	Stud and Bolt, Rocker Arm Shaft	M12 X 1.75	101–116	(75–86)
Refer to section 1.21.2.1	Nut, No. 1&5 Camshaft Cap	M12 X 1.75	101–116	(75–86)
Refer to section 1.21.2.1	Stud, No. 1&5 Camshaft Cap	M12 X 1.75	101–116	(75–86)
Refer to section 1.22.5	Bolt (Solid), Camshaft Drive Gear–to–Camshaft	M18 X 1.5	75 (+90°)	55 (+90°)
Refer to section 1.23.4	Bolt, Camshaft Drive Gear Retaining	M18 X 1.5	425	310
Refer to section 1.21.2.1	Nut, Adjustable Idler Assembly.	M12 X 1.75	57–67	(42–49)
Refer to section 1.21.2	Bolt, Bull Gear Assembly–to–Block	M12 X 1.75	101–116	(75–86)
Refer to section 1.28.4	Nut, Accessory Drive Pulley	M24 X 1.0	220–250	(162–184)
Refer to section 1.6.3.1	Screw, Breather–to–Rocker Cover	–	2.5	(22 lb·in.)
Refer to section 1.2.4	Bolt, Wiring Harness Flange	–	10–15	(7–11)
Refer to section 1.2.3.1	Bolt, Injector Crab	–	58–66	(43–49)

SECTION	FASTENER	SIZE	N·m	(lb·ft)
Refer to section 1.27.3	Cap Screw	M8	34	(25)
Refer to section 1.27.3	Cap Screw	M10	48	(35)
Refer to section 1.27.3	Cap Screw	M12	115	(85)

Table 1–31 Exceptions to Standard Fastener Torque Specifications

Service Tools

Listed in Table 1–32 are the service tools used in this section.

TOOL No.	TOOL NAME
PT–7276	Gasket Eliminator (Loctite 51580).
J 22273–01	Cylinder Liner Depth Gage
J 22405–02	Piston Ring Pliers
J 22738–02	Valve Spring Tester
J 23479–100	Collet (Exhaust)
J 23479–271	Valve Seat Remover (Exhaust)
J 23479–29	Collet (Exhaust)
J 23479–460A	Valve Seat Insert Remover (Intake)
J 25026	Flywheel Lifting Sling
J 23059–01	Setting Master Range Fixture
J 25076–B	Valve Spring Tester
J 26558–92	Pipe Sealant (PT 7271)
J 29109	Universal Engine Stand
J 33190	Valve Seat Insert Installer (Intake)
J 34696–B	Valve Guide Remover
J 34983	Valve Seat Insert Installer (Exhaust)
J 35580	Valve Spring Compressor (Head Installed)
J 35595	Eye Bolts–Lifting
J 35596	Camshaft and Idler Gear Lash Adjusting Tool Set
J 35599	Valve Stem Sealer Installer
J 35596–15	Gear Lash Pedestal
J 35597	Cylinder Liner Installation Tool
J 35598	Piston Ring Compressor
J 35623–A	Valve Guide Pilot
J 35636–A	Cylinder Head–Engine Stand Adaptor
J 35635–A	Engine Cylinder Block and Stand Adaptor Plates
J 35641–A	Cylinder Head Lifter Bracket
J 35642–1	Base Post
J 35642	Crankshaft Gear Remover and Installer
J 35651	Gear Case Alignment Plug
J 35652–A	Camshaft Gear Torque Holding Tool
J 35653	Cup Plug Driver Set (used with handle J 7079–2)
J 35686–A	Front and Rear Oil Seal Expander and Installer (Std, OS, and Wear Sleeve)
J 35687	Water Pump Lash and Impeller Slip Tester
J 35784	Guide Studs–Cylinder Head
J 35785	Guide Studs–Bull Gear and Flywheel Housing

TOOL No.	TOOL NAME
J 35791	Cylinder Liner Removal Tool
J 35884–A	Piston Groove Gages
J 35906	Camshaft Gear Pilot
J 35945	Connecting Rod Guides
J 35951	Hydraulic Shop Press
J 35951–175	Hydraulic Ram and Pump (included in J 35951)
J 35984–1	Dummy Fuel Injectors
J 35984–2	Thermostat Inlet Cover
J 35985–2	Adaptor
J 35993	Front and Rear Oil Seal Remover
J 35994	Crankshaft Protector
J 35599	Valve Stem Seal Installer
J 36003–A	Socket–Rocker Arm Shaft Stud
J 36024–C	Accessory Drive Service Set
J 36024–1	Roller Bearing Installer
J 36024–2	Needle Bearing Installer/Remover
J 36024–3	Accessory Drive Holding Fixture
J 36024–4	Seal Installer
J 36107	Guide Studs–Gear Case and Exhaust Manifold
J 36187–A	Main Bearing Remover
J 36211	Piston and Connecting Rod Holding Fixture
J 36223–7A	Water Inlet Cover Plate
J 36223–D	Cylinder Block Pressure Test Kit
J 36224	Dowel Installation Set
J 36224–1	Dowel Installer
J 36224–2	Dowel Installer
J 36235	Guide Studs–Flywheel and Crankshaft Pulley
J 36237	Engine Barring Tool
J 36326	Cup Plug Installer–Rocker Shaft
J 36347	Valve Button Retainer Expander
J 36375	Flywheel Lock
J 37075–A	Crank Oil Wear Sleeve Remover
J 38189	Head Bolt Resurface
J 38609–A	3.5mm Fire Ring Gage
J 38662	Accessory Drive Gear Lash Tool
J 38689–A	Piston Ring Land Step Gage
J 38977–A	Water Pump Gear Lash Checker
J 39109	Valve Stem Seal Installer
J39647–A	Rocker Arm and Shaft Assembly Lifter
J 39652	Engine Stand Adaptor Plate
J 39814–A	Balance Shaft Assembly Support

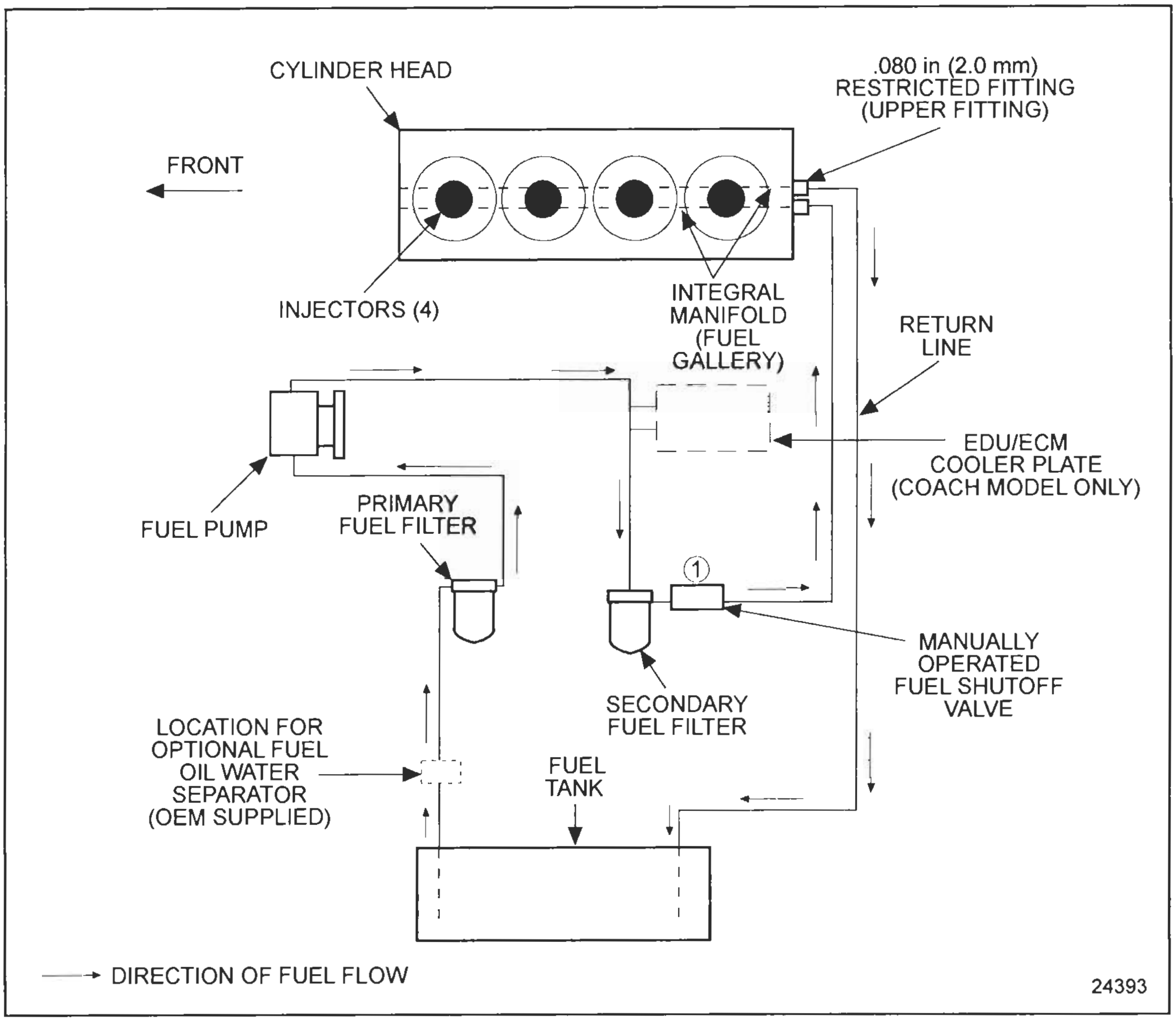
TOOL No.	TOOL NAME
J 39816	Oil Pump Gear Holding Tool
J 39817	Balance Shaft Installation Pilot
J 5347–B	Cylinder–Dial Bore Gage
J 5437	Valve Guide Cleaners
J 7040–A	Valve Seat Grinder
J 7079–2	Driver Handle
J 8062–1	Valve Spring Compressor
J 8062–3	Valve Spring Compressor with jaws
J 8165–2	Dial Gage
J 9737–C	Flywheel Tool Set
J 9737–3	Base Post

Table 1–32 Service Tools

2 FUEL SYSTEM

2.1 FUEL SYSTEM OVERVIEW

For a schematic diagram of a typical fuel system, see Figure 2-1.



1. Effective with 6R56762 a manually operated fuel shutoff valve replaced a check valve. A PRO–CHEK® valve may be installed at this location to remove air.

Figure 2–1 Schematic Diagram of the Fuel System

The fuel system includes injectors, integral fuel manifold in the cylinder head, fuel pump, a cooling plate for the Electronic Control Module (ECM), a primary fuel filter, a secondary fuel filter, and a fuel shut off valve if equipped. An 2.0 mm (.08 in.) restrictive orifice is located in the fuel return fitting at the rear of the cylinder head to maintain the pressure in the fuel system.

CAUTION:

When the temperature of diesel fuel is elevated, as occurs when the fuel is circulated through an operating engine, it may pose the following hazards which should be guarded against.

- **Heated liquid fuel may cause scalding if allowed to come in contact with the skin. Heated diesel fuel can form combustible vapor mixtures in the area around the fuel source.**
- **Whenever possible, it is recommended that the engine and fuel be given an opportunity to cool down to ambient temperature before performing service operations which could result in spillage of fuel from the engine or vehicle fuel system.**
- **When this is not possible, protective clothing (face shield, insulated gloves, apron) should be worn when performing these operations.**
- **Engine or vehicle fuel systems service operations should be performed in a well ventilated area that is kept free of bystanders.**
- **Keep open flames, sparks or other potential ignition sources away and do not smoke during vehicle refueling and service operations which could result in the escape of liquid or vaporized diesel fuel.**

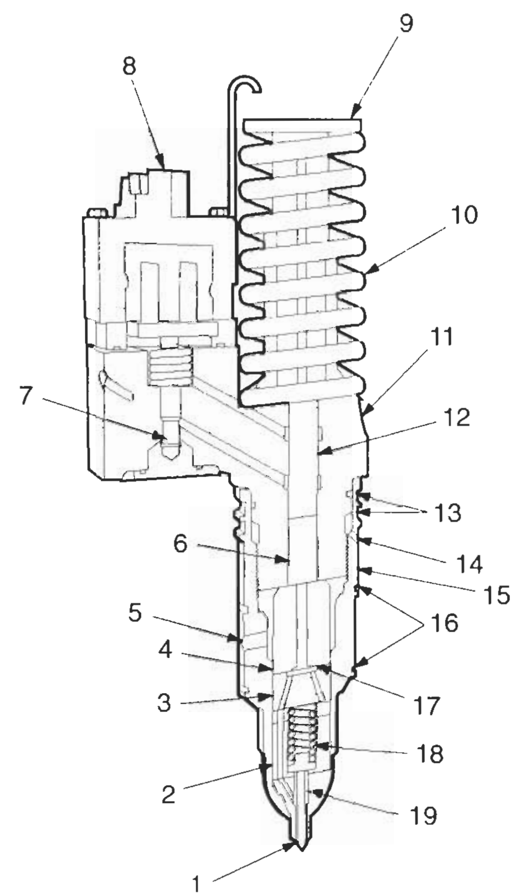
Fuel is drawn from the fuel tank through an optional fuel water separator, into the primary fuel filter and enters the pump. After leaving the fuel pump under pressure, the fuel flows through the ECM cooler plates (if equipped) through the secondary fuel filter to the cylinder head. An optional PRO–CHEK® check valve that removes air from the fuel supply line may be installed between the secondary filter and the cylinder head. The fuel flows to the injectors in the cylinder head through passages integral with the head. Surplus fuel exits at the rear of the head just above the inlet, through a restrictive return fitting which maintains fuel pressure in the system and returns back to the fuel tank.

2.2 ELECTRONIC UNIT INJECTOR

The Electronic Unit Injector (EUI) is a lightweight, compact unit that injects diesel fuel directly into the combustion chamber. See Figure 2-2. The amount of fuel injected and the beginning of injection timing is determined by the ECM. The ECM sends a command pulse which activates the injector solenoid. The EUI performs four functions:

- ❑ Creates the high–fuel pressure required for efficient injection.
- ❑ Meters and injects the exact amount of fuel required to handle the load.
- ❑ Atomizes the fuel for mixing with the air in the combustion chamber.
- ❑ Permits continuous fuel flow for component cooling.

Engine combustion is obtained by injecting, under pressure, a small quantity of accurately metered and finely atomized fuel oil into the cylinder. Metering and timing of the fuel is accomplished by the ECM which actuates the solenoid poppet valve to stop the free flow of fuel through the injector. When the solenoid poppet valve closes, fuel is trapped in the injector body and under the plunger. The continuous fuel flow through the injector prevents air pockets in the fuel system and cools those injector parts subjected to high combustion temperatures.



1. Spray Tip
2. Spring Cage
3. Check Valve Cage
4. Spacer
5. Fuel Inlet Opening
6. Fuel Supply Chamber
7. Poppet Control Valve
8. Solenoid
9. Injector Follower
10. Injector Follower Spring
11. Injector Body
12. Plunger
13. Upper O–ring Grooves and Seals
14. Fuel Outlet Openings
15. Injector Nut
16. Lower O–rings Grooves and Seals
17. Flat Disk Check Valve
18. Injector Needle Valve Spring
19. Needle Valve

Figure 2–2 Electronic Unit Injector Cross–section

Fuel enters the injector through the two fuel inlet filter screens located around the injector body. See Figure 2-3. Filter screens are used at the fuel inlet openings to prevent relatively coarse foreign material from entering the injector.

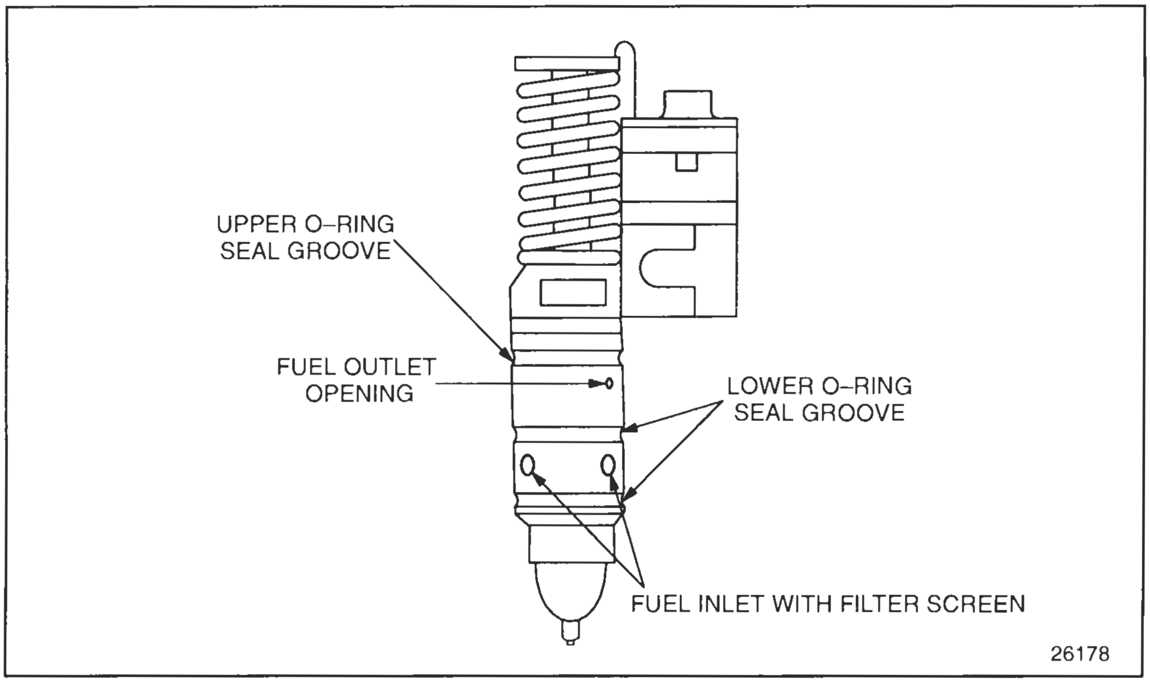


Figure 2-3 Electronic Fuel Injector

After entering the nut cavity, the fuel passes through a drilled passage into the poppet control valve and plunger area. See Figure 2-2.

Outlet openings, through which the excess fuel oil returns to the fuel return manifold and then back to the fuel tank, are located around the injector nut. See Figure 2–4.

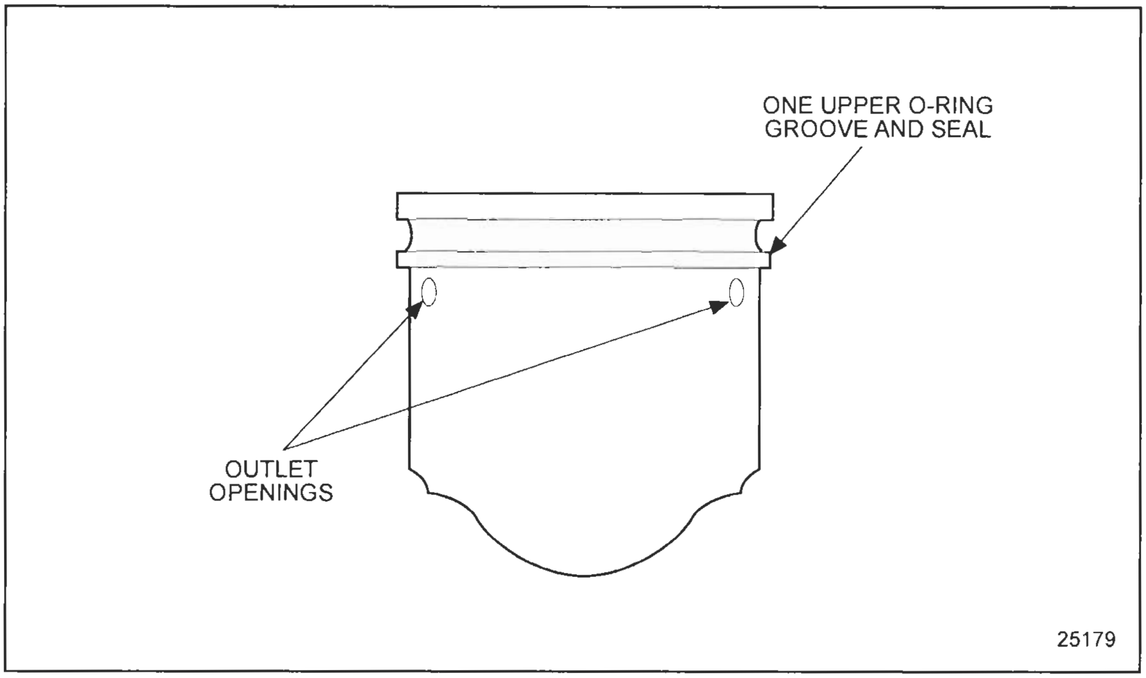


Figure 2–4 Fuel Outlet Openings in the Fuel Injector Body

The plunger operates up and down in the body bore of the injector. The motion of the injector rocker arm is transmitted to the plunger and follower that bears against the follower spring.

As the piston moves approximately two–thirds of the way up in the cylinder on the compression stroke, the injector cam lobe begins to lift causing the injector rocker arm to push down on the follower and the plunger. Just before injection begins, the ECM sends an electronic pulse which turns on the injector solenoid. The energized solenoid creates a magnetic force which pulls the armature up, closing the poppet valve and trapping fuel under the plunger and passages leading down to the needle valve. The fuel pressure increases as the plunger continues its downward stroke.

A flat disk check valve is built into the injector fuel passages between the plunger and the tip. This check valve normally has no effect on the injection process but will function to prevent cylinder gases from blowing back into the injector and fuel system if a particle of debris should become lodged between the needle and seat or the tip assembly fails.

This fuel pressure acts on the needle valve. When it creates a force high enough to overcome the valve spring force holding the needle on its seat, the needle valve moves up, allowing the high pressure fuel to spray into the combustion chamber. The high pressure of the fuel passing through the small holes in the tip creates a finely atomized spray for combustion within the cylinder.

After the pulse width time has passed, the ECM turns off the current to the injector solenoid. The de-energized solenoid allows a spring to open the poppet valve, permitting the trapped fuel to spill down, dropping the pressure within the injector. When the pressure is low enough the needle valve closes and ends injection.

The beginning of injection and metering of the fuel in relation to the crankshaft position are controlled by the ECM. Injection begins soon after the poppet valve is closed. The valve closing point information, known as the response time feedback, is returned to the ECM. This information is used to monitor and adjust injection timing, thus removing injector-to-injector variation influences on timing. The amount of fuel injected depends on the pulse width stored in the calibration which determines how long the poppet valve remains closed; the larger the pulse width the longer the valve is closed and the more fuel is injected.

When the injector rocker arm has completed its downward travel the injector follower spring returns it to the starting position. As the plunger moves up fuel enters the injector pumping cavity for another injection cycle. The constant circulation of fuel through the injector renews the fuel supply in the chamber and aids the cooling of the injector.

2.2.1 Repair or Replacement of Electronic Unit Injector

To determine if repair is possible or replacement is necessary perform the following procedure. See Figure 2-5.

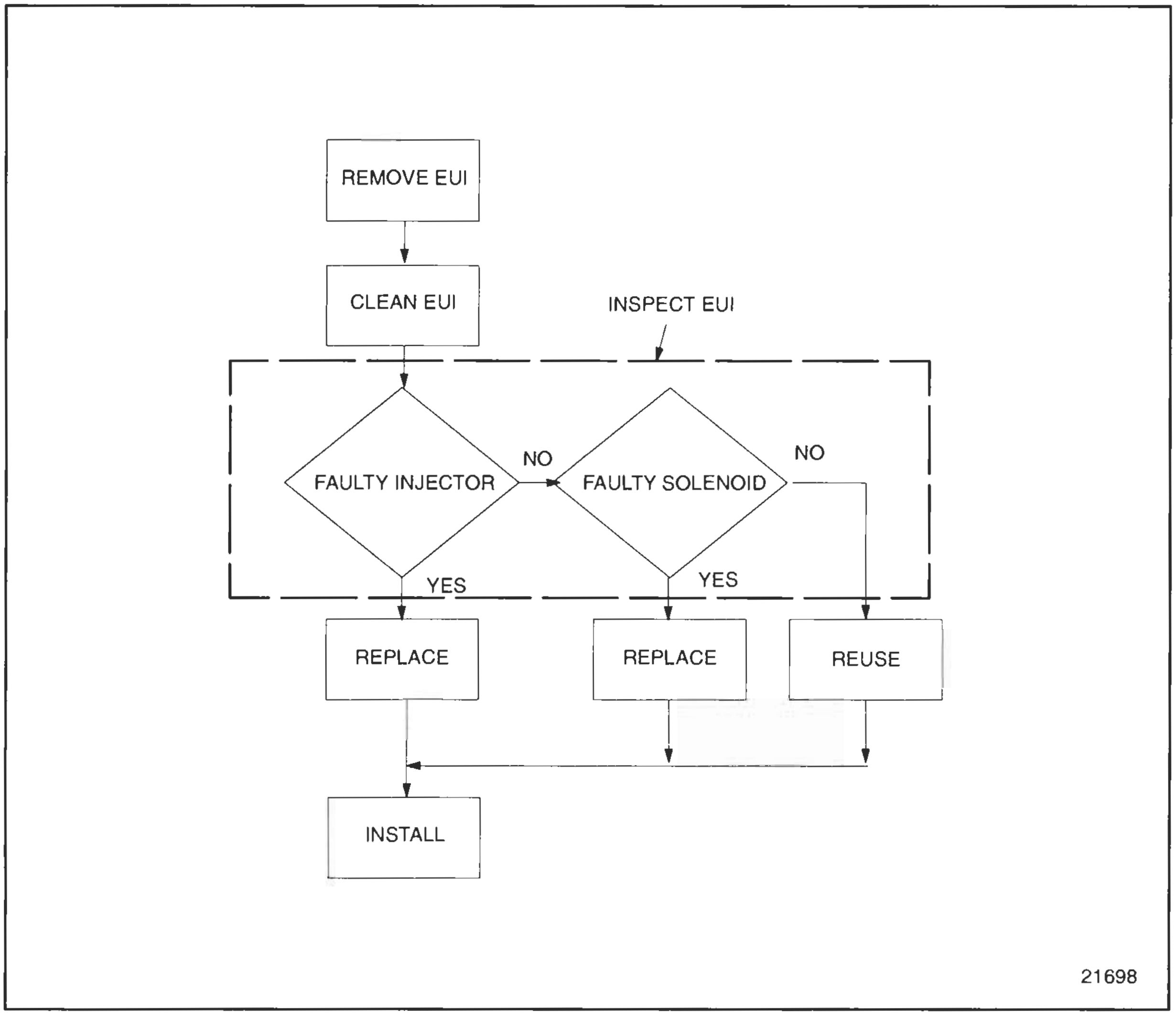


Figure 2–5 Flowchart for Repair or Replacement of EUI

2.2.2 Unit Injector Removal

The following steps must be performed prior to removing an injector:

NOTE:
The solenoid can be replaced without removing the injector. Refer to section 2.2.4.

1. Clean the valve rocker cover around its seat on the head, and in the attaching bolt recesses.
2. Remove the valve rocker cover. Refer to section 1.6.2.
3. Drain the cylinder head fuel gallery by removing the fuel gallery plugs.

NOTE:
Loosening the fuel line at the inlet fitting will allow fuel to flow faster. Carefully collect the drained fuel in an appropriate container.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

NOTICE:

All the fuel must be removed from the cylinder head before removing an injector to prevent the fuel from entering the cylinder and causing hydrostatic lock or washdown. If the head is not thoroughly purged of fuel before an injector is removed, fuel remaining in the fuel manifold will drain into the cylinder filling the piston dome recess. It cannot drain from the dome and, if not removed, can cause hydrostatic lock and bend the connecting rod.

4. Remove the inlet and outlet lines from the fittings at the rear of the cylinder head. Blow low pressure compressed air into the inlet fitting for 20 to 30 seconds or until all of the fuel is purged from the cylinder head. See Figure 2-6.

NOTE:
Front and rear rocker shaft assemblies look identical but are not interchangeable because of different bolt hole center distances. The outboard end of each rocker shaft assembly is marked with the DDC logo for identification. Care should be taken to identify and return assemblies to the proper location if both overhead assemblies are removed.

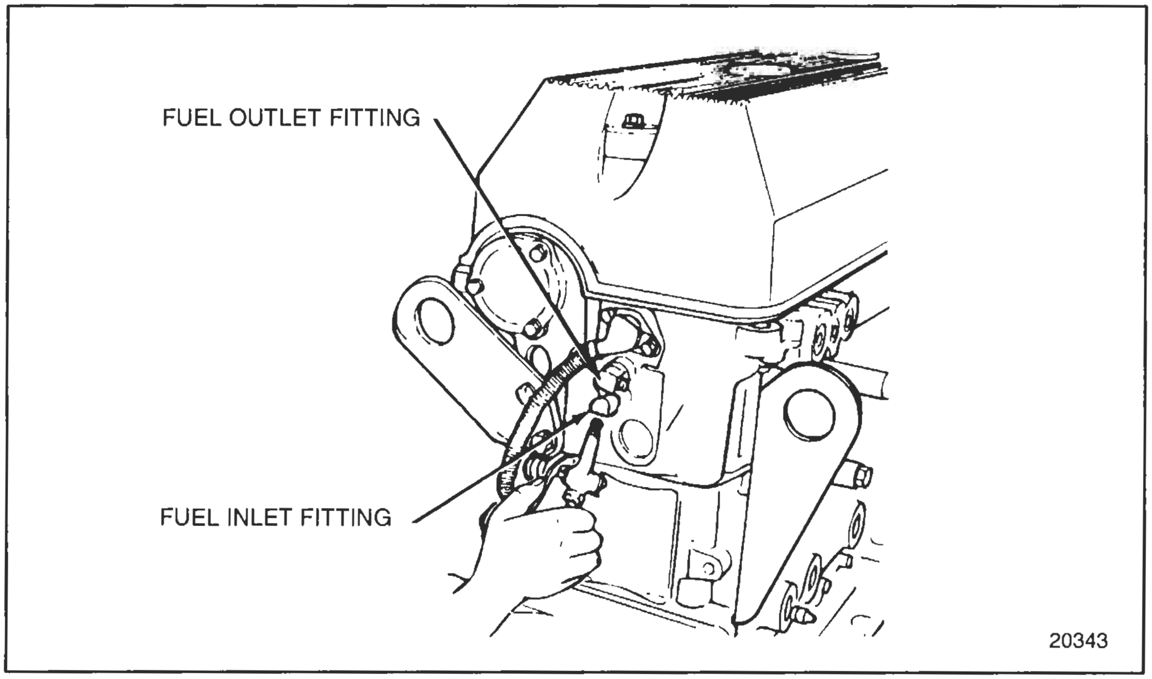


Figure 2–6 Cylinder Head Fuel Fitting Locations

5. Remove the two rocker shaft thru–bolts and one nut for each rocker shaft assembly, and lift the rocker shaft assembly off the engine as outlined in the first section of this manual. Refer to section 1.3.2, step 3.

To remove the injector, complete the following steps:

NOTICE:
Do not remove the screws from the injector. The terminal wires have keyhole slots to fit over the screw head. Turning the screws will damage the threads in the solenoid housing.

1. Loosen the injector wire terminal screws two full turns and remove the terminal wires.
2. Remove injector hold down crab.

NOTICE:
Do not remove the screws from the injector. The wire terminals have keyhole slots to fit over the screw head. Turning the screws too far will damage the threads in the injector solenoid housing.

NOTICE:
Extreme care should be used when handling an EUI to avoid costly damage by dropping or otherwise mishandling the EUI.

NOTE:
When replacing an EUI, always replace the injector O–rings.

3. Lift the injector from its seat in the cylinder head by inserting a pry bar under the injector body. See Figure 2-7.

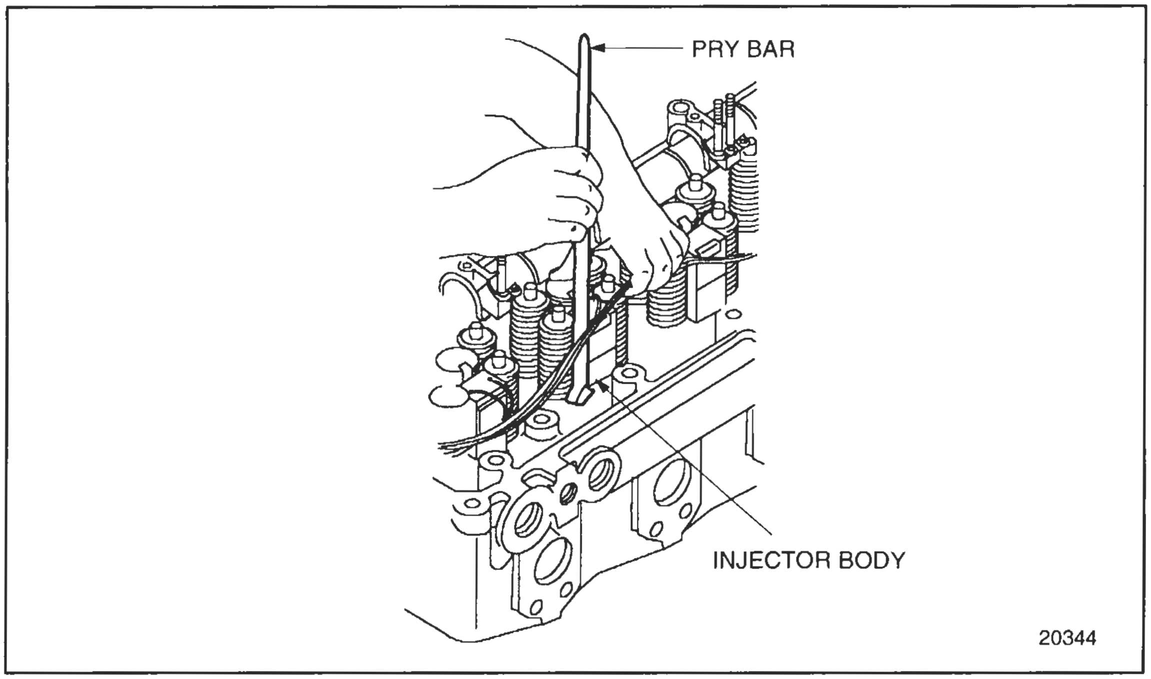


Figure 2-7 Removing EUI

NOTICE:
Avoid wire brushing the spray holes to prevent damage.

4. Cover the injector hole in the cylinder head to keep out foreign material. Remove carbon from the injector exterior in the area where the tip joins the nut, using wire buffing wheel, J 7944.

2.2.3 Disassembly of Electronic Unit Injector

On a Series 50 EUI, only the injector solenoid and seal rings are serviceable. The injector must not be disassembled.

2.2.3.1 Inspection of the Electronic Unit Injector

The solenoid can be tested either on or off of the injector.

To clean and inspect the injector, complete the following steps:

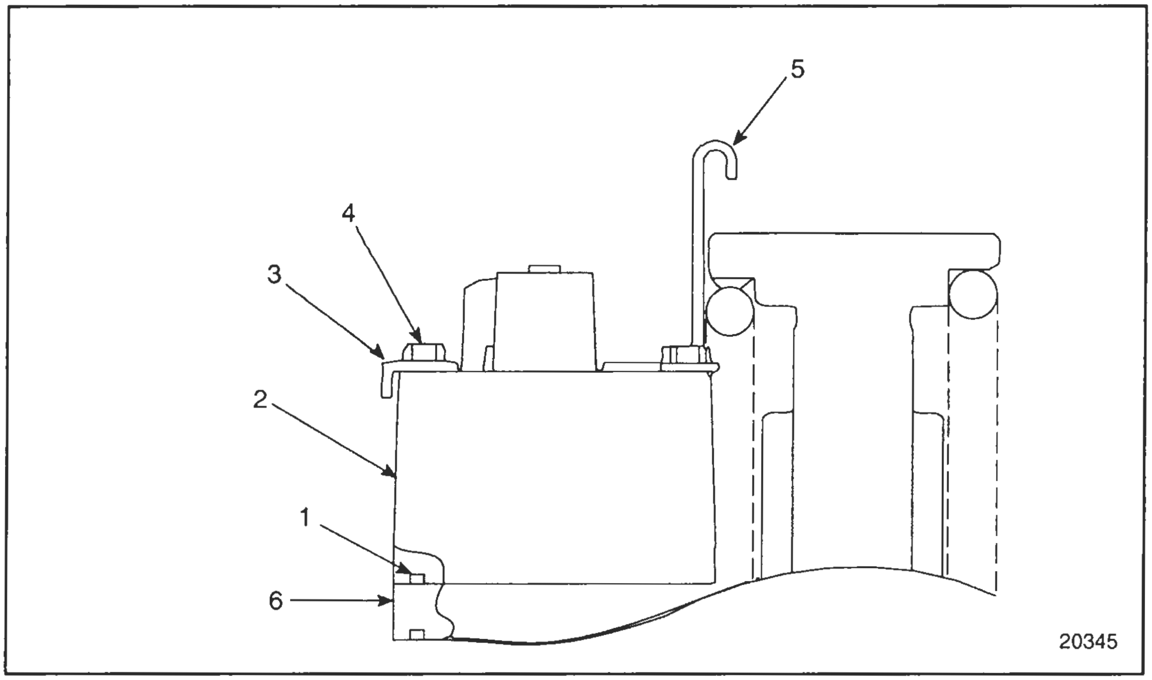
CAUTION:
To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

1. Clean the exterior of the injector with clean solvent and dry it with compressed air.
2. Test the EUI using J 34760 injector pop–n–fixture. Follow procedures supplied with this tool. Reuse or replace injector or injector and solenoid as indicated. Inspect the O–rings for damage or foreign material. Replace O–rings.
3. Inspect the fuel injector tubes at the injector seat. If required, replace the fuel injector tubes.

2.2.4 Repair of Fuel Injector Solenoid and Seals

Perform the following steps for solenoid replacement:

1. Loosen the injector wire terminal screws two turns and remove terminal wires.
2. Loosen four (4) hex head screws and remove old solenoid. See Figure 2–8.



1. Spacer Seals
2. Solenoid
3. Load Plate
4. Screw
5. Follower Retainer
6. Spacer

Figure 2–8 EUI Solenoid Assembly

3. This step is different depending on the DDEC unit used:
   [a] For DDEC II, discard the solenoid, load plate, follower retainer, and screws. Do not reuse old screws.
   [b] For DDEC III, discard the solenoid, follower retainer, and screws. Do not reuse old screws. The load plate must be reused.
4. Remove spacer and seals from injector body.

NOTICE:
The spacer is a matched component with the armature and must remain with its respective injector

5. Discard seals, but do not discard spacer.

6. Install new seal in spacer groove and position spacer on body with seal facing down. See Figure 2-8. Seal may be retained in groove with small quantity of grease.
7. Install new seal in solenoid groove.
8. Install solenoid on spacer.

NOTICE:
For DDEC III, reuse old load plate, follower retainer, screws or screw washers (if used), since this may result in solenoid damage, screw damage or both.

NOTICE:
The load plate on each DDEC III injector is unique and must remain with the injector. The DDEC III load plate carries the injector part number, it's injector serial number in bar code format, and the injector calibration code number.

9. Install new screws through load plate and follower retainer, solenoid, and spacer.

10. Thread screws into body and tighten all screws until heads contact retainer and load plate with a slight force (less than 5 lb·in. [0.6 N·m] torque) in the sequence shown. See Figure 2-9.

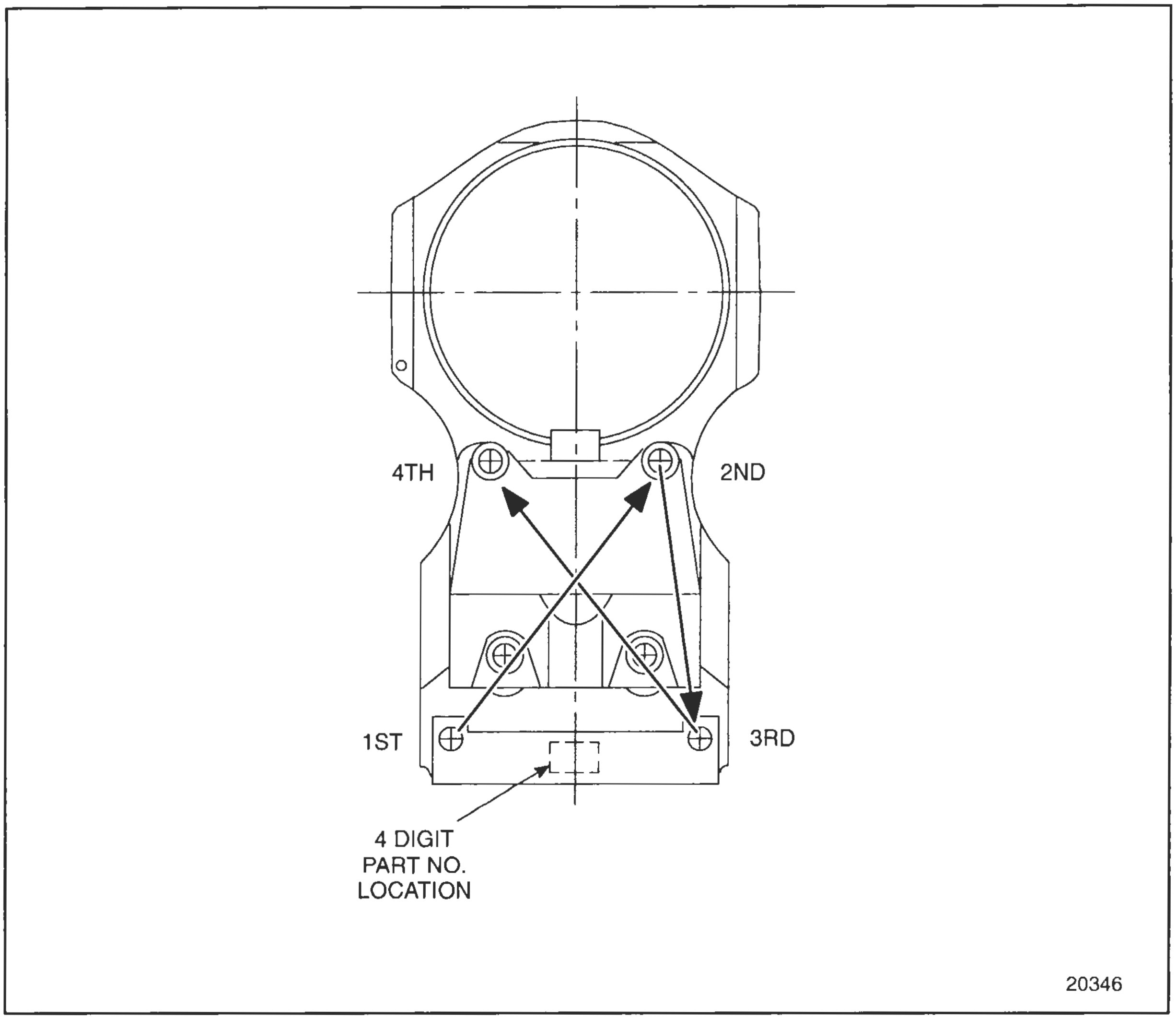


Figure 2-9 EUI Solenoid Torque Sequence

11. Tighten screws to 2 N·m (19 lb·in.) torque in the sequence shown. See Figure 2-9.

12. On DDEC II injectors only, etch the last four digits of injector part number on the load plate. See Figure 2-9.

2.2.5 Installation of the Electronic Fuel Injector

Perform the following steps to install the EUI:

1. If the fuel system is contaminated with coolant:
   - [a] Drain the fuel tanks and refill with clean fuel.
   - [b] Replace both filters with new, and clean the fuel/water separator, if equipped.
   - [c] Inspect fuel injectors for damage and replace as required.
2. If the coolant system is contaminated with fuel, flush and reverse flush the system. Refer to section 13.5.4.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

NOTICE:

Leftover fuel must be removed from the injector bore before injector installation. If fuel is trapped between the top of the injector hole tube and the lower injector O–ring seal, it may seep down to the injector hole tube seal ring, causing swelling and possible seal leakage.

3. Using clean compressed air, blow out any fuel remaining in the injector bore.

NOTE:
If the engine is equipped with an auxiliary injector tube seal, replace it with a new seal when the injector is removed.

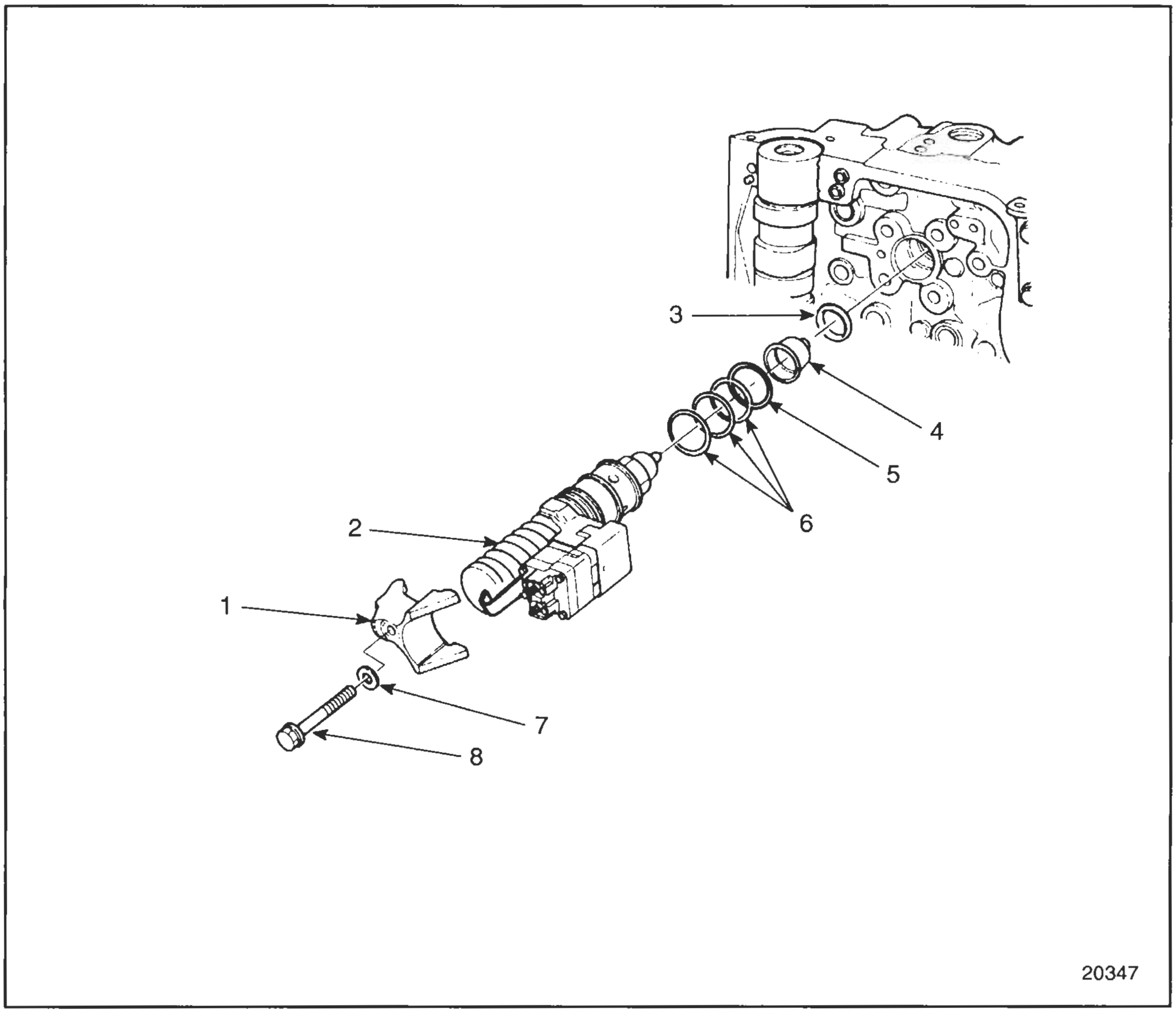
NOTICE:
Do not use a metal dowel as this may damage the seal.

NOTICE:
Injector seals are considered one–use items and cannot be reused. Any time an injector is removed, all three injector nut O–ring seals must be replaced with new seals. Failure to replace seals can result in seal leakage.

4. Detroit Diesel encourages the use of an additional service seal (5104701) that is impervious to both coolant and fuel. This seal should be used in situations where injector tube seal leakage or deterioration is suspected or confirmed. Place the auxiliary seal in the injector hole and seat it against the top of the injector tube with a 41.3 mm (1–5/8 in.) diameter wood or plastic dowel.
5. Check to make sure the injector bore is thoroughly clean.
6. Apply a thin coat of clean ethylene glycol to the injector seal rings and install them in the injector nut ring grooves. Make sure seals are properly seated.
7. Insert the injector into its respective injector tube bore. Visually align the injector body for equal clearance between valve springs (there is no locating dowel pin on the underside of the EUI). After locating the injector, press down on the top of the injector body with the heel of your hand to seat it in the injector tube.

NOTE:
Before installing injectors, the injector tube bore should be cleaned refer to section 2.3.3 and inspected for any damage.

NOTICE:
The hemispherical portion of the hold–down crab washers must be installed facing the crab (pointing down) in order to prevent damage to the washers. See Figure 2–10.



1. Injector Hold–down Crab
2. Electronic Unit Injector
3. Injector Tube O–ring
4. Injector Tube
5. Auxiliary Injector Seal
6. Injector O–rings
7. Hold–down Crab Washer
8. Hold–down Crab Bolt

Figure 2–10 Electronic Unit Injector and Related Parts

8. Install the hold down crab, hemispherical crab washer (flat surface up against bolt) and hold down bolt to the injector. See Figure 2-11. Be sure that the clamp does not interfere with the injector follower spring or valve springs.
9. Tighten the hold down bolt to 43-49 lb·ft (58-66 N·m).

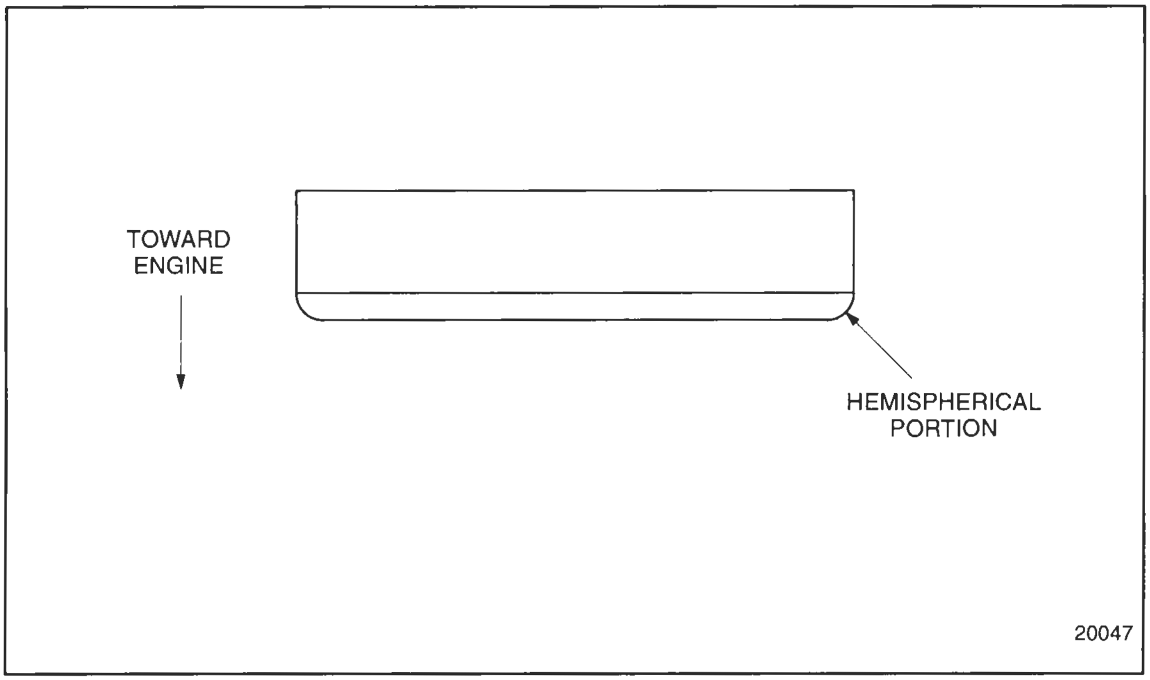


Figure 2-11 Hold-down Crab Washer Installation

Perform the following steps for installation of the injector hold-down crab:

10. Determine which type of hold-down crab needs to be installed by measuring the overall height.
    [a] If the overall height is 54 mm (2.125 in.), proceed to step 11.
    [b] If the overall height is 52 mm (2.047 in.), skip to step 12.
11. Position a 0.762 mm (.030 in.) feeler gauge between the crab and injector spring on the side of the spring that faces the intake manifold.

NOTICE:

The hemispherical portion of the hold–down crab washers must be installed facing the crab (pointing down) in order to prevent damage to the washers. See Figure 2–12.

12. Install the hold–down crab, hemispherical crab washer (flat surface up against bolt) and hold–down bolt to the injector. See Figure 2–12. Be sure that the clamp does not interfere with the injector follower spring or valve springs.
13. Tighten the hold down bolt to 43–49 lb·ft (58–66 N·m).
    [a] If a former crab was installed remove the feeler gauge after torquing the bolt.

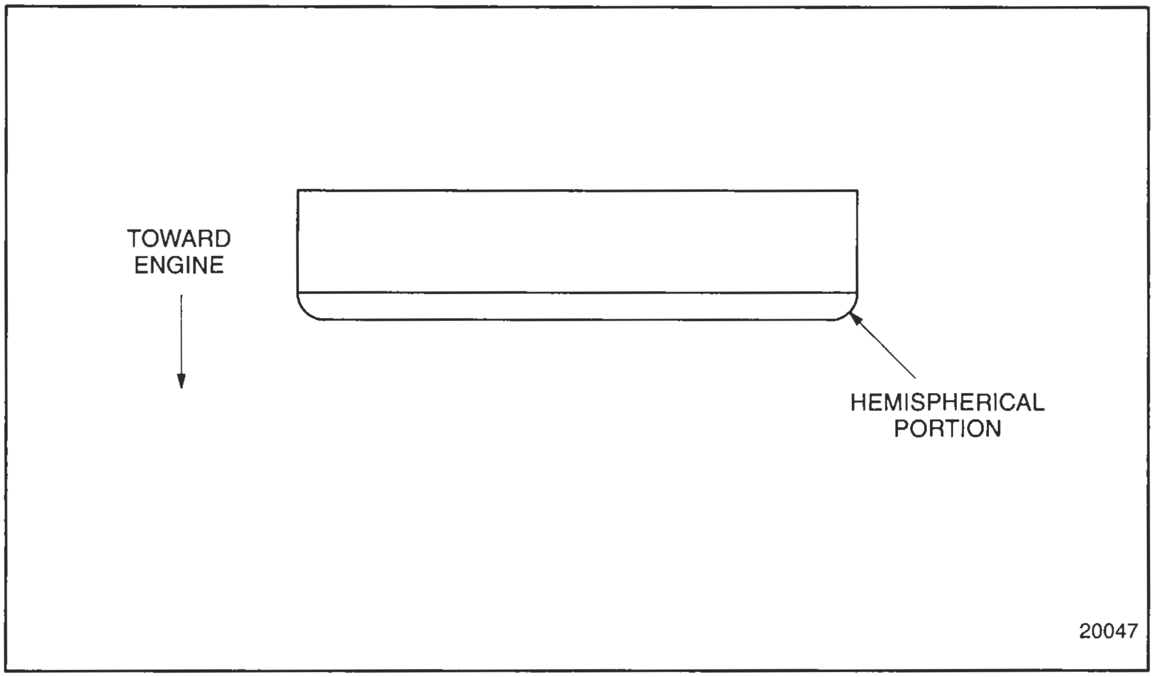


Figure 2–12 Hold–down Crab Washer Installation

2.2.6 Installation of the Electronic Unit Injector (Continued)

Perform the following steps to complete the installation of the EUI:

1. Install the EUI terminal wires by positioning the keyhole in the terminal over the screw in the injector solenoid housing. Pull the terminal end down so that the screw rests in the smaller slot in the terminal. Tighten the screws to 12–17 lb·in. (1.4–2.0 N·m). Do not bend the terminals down after installation. See Figure 2–13.

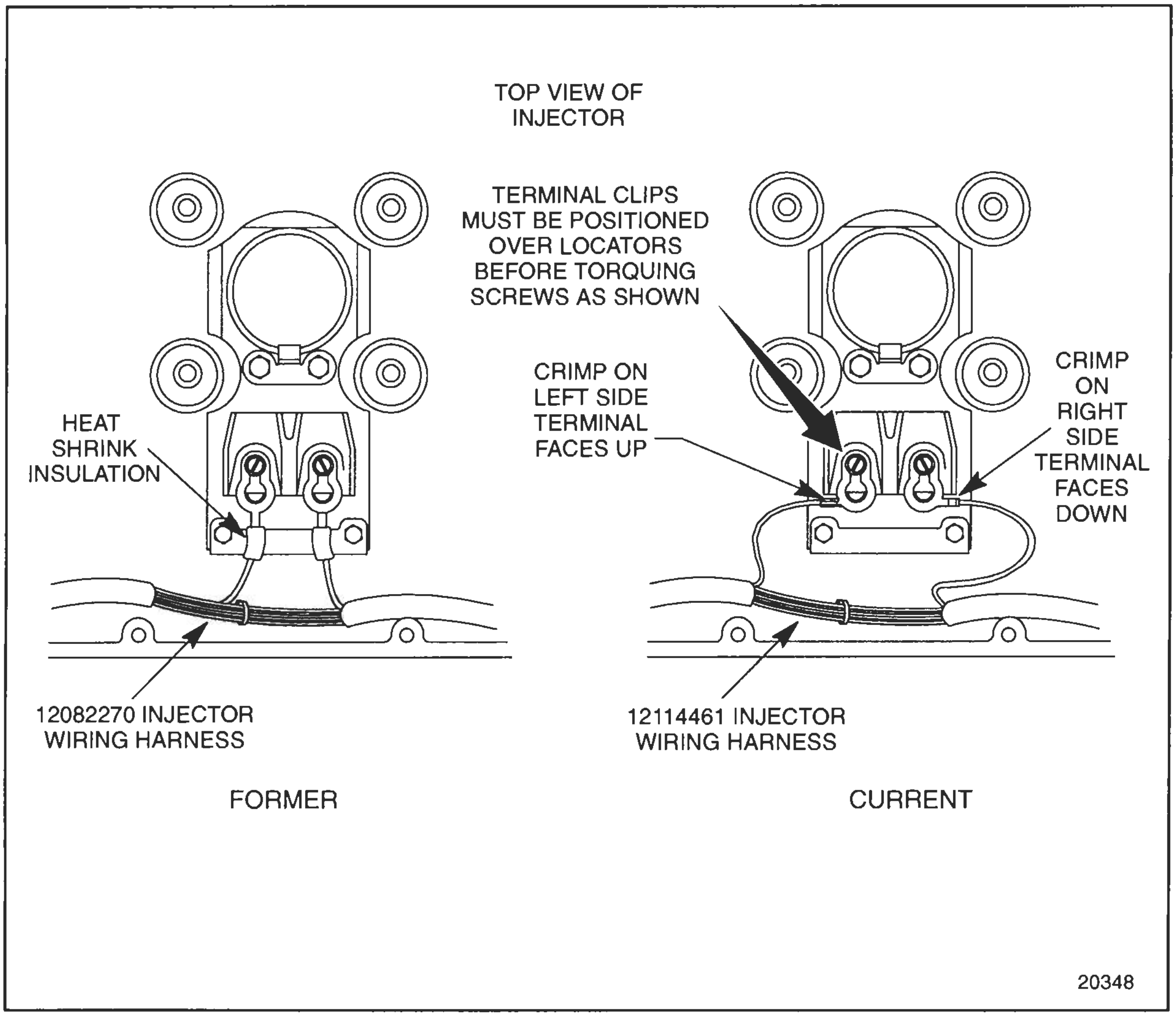


Figure 2–13 EUI Terminal Installation

NOTE:
Front and rear rocker shaft assemblies look identical but are *not interchangeable* due to different bolt hole center distances. The outboard end of each rocker shaft assembly is marked with the DDC logo for identification. Care should be taken to identify and return assemblies to the proper location if both overhead assemblies were removed.

2. Install the rocker arm shafts, with rocker arms in place. Refer to section 1.3.3.
3. Adjust the intake and exhaust valve clearances and injector height. Refer to section 12.2.
4. Install the inlet and outlet fuel lines to the fittings at the rear of the cylinder head.
5. On DDEC III engines, record the injector calibration code from the load plate with the proper cylinder location.
6. Install the valve rocker cover. Refer to section 1.6.4.
7. Once installed–turn ignition on. Plug in DDR to DDL connector, and select injector calibration. View injector calibration to ensure injector calibration is correct for each cylinder. If not correct, select update injector calibration and set correctly

2.3 FUEL INJECTOR TUBE AND O–RING

The bore in the cylinder head for the EUI is directly through the cylinder head water jacket. To prevent coolant from contacting the injector and still maintain maximum cooling of the injector, a copper tube is pressed into the injector bore. The tube has a ring seal at the top and is flared at the bottom, on the lower side of the cylinder head, to create water and gas tight joints at the top and bottom.

NOTE:
It is recommended that the injector tube be replaced with new parts at the time of engine overhaul.

2.3.1 Repair or Replacement of Fuel Injector Tube

To determine if repair or replacement of the fuel injector tube is necessary. See Figure 2–14.

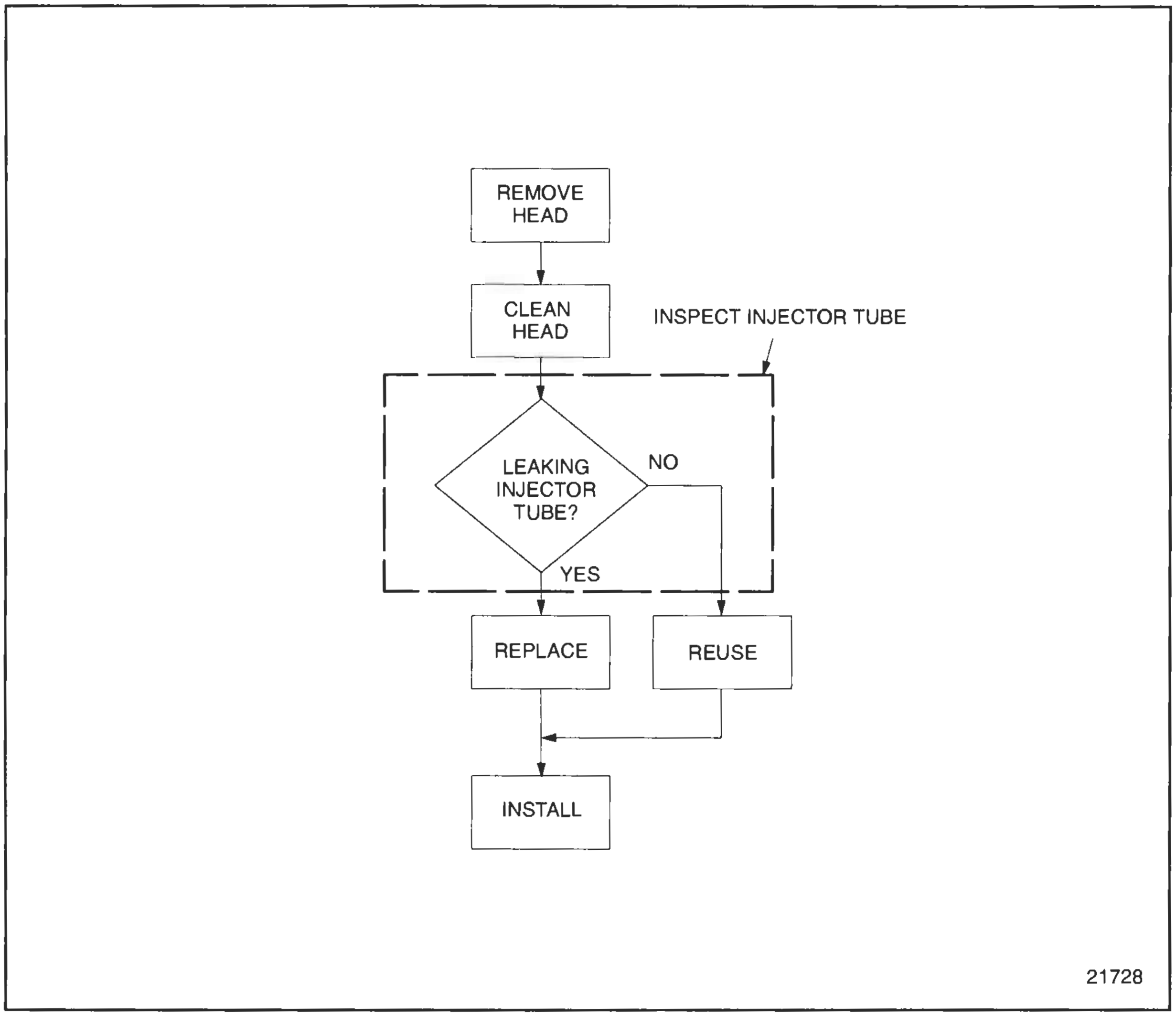


Figure 2–14 Flowchart for Repair or Replacement of Fuel Injector Tube

2.3.2 Removal of the Injector Tube and O–Ring

When removing an injector tube, use injector tube installation, removal and refinishing tool set, J 33880.

1. Remove, disassemble and clean the cylinder head. Refer to section 1.2.2.
2. Place the injector tube installation/removal tool, J 33880–4, in the injector tube. Insert the pilot, J 5286–5, through the small opening of the injector tube and thread the pilot into the tapped hole in the end of the installation/removal tool. See Figure 2–15.

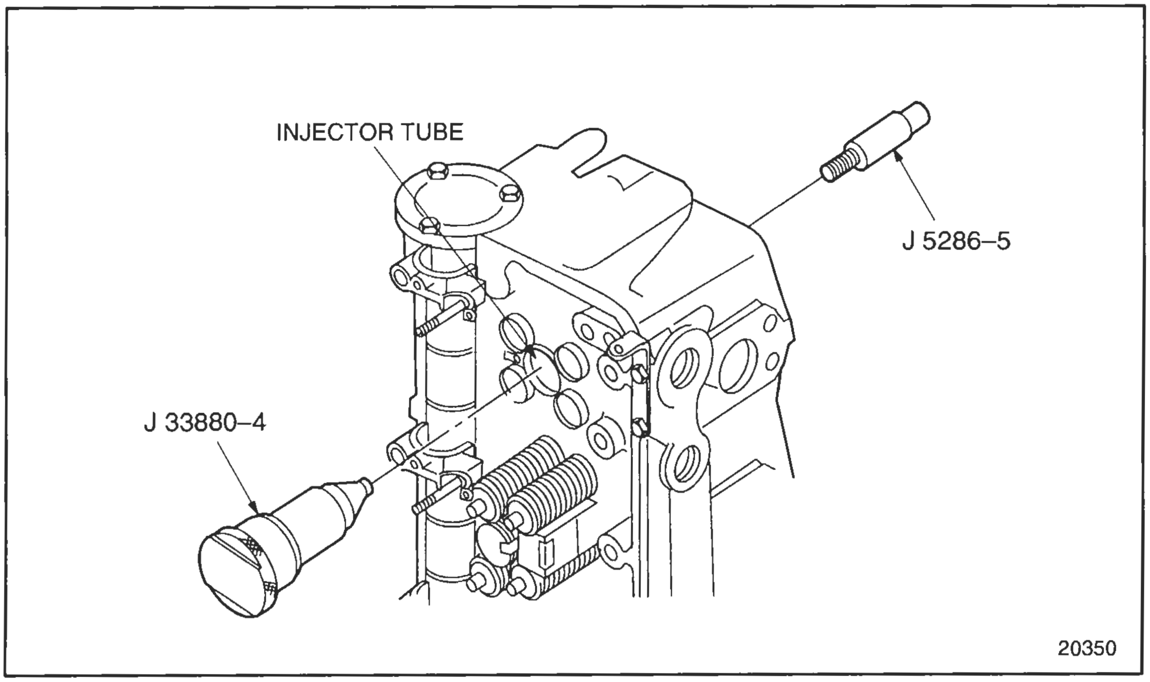


Figure 2–15 Removal of Injector Tube

3. Tap on the end of the pilot using a brass hammer or fiber mallet. Carefully drive and lift the injector tube, installation/removal tool and pilot from the cylinder head. If the injector tube O–ring is not removed with the injector tube, remove the O–ring from the cylinder head casting at the upper end of the injector tube bore.

2.3.3 Cleaning of Injector Tube

Thoroughly clean the injector tube hole in the cylinder head to remove any dirt, burrs, or foreign material that may prevent the new tube from seating at the lower end or sealing at the upper end. Excess material in the form of a small copper ring may be left at the lower end of the injector tube counterbore after the injector tube has been removed. This copper ring will have to be removed using a suitable sharp pointed tool.

2.3.4 Installation of Auxiliary Injector Seal

Perform the following for installation of auxiliary injector seal.

NOTICE:
If a cylinder head has a damaged injector hole tube seal, coolant may seep past the seal after injector removal, drain down the injector tube hole, and fill the combustion chamber. If this condition goes undiscovered and the coolant is not removed from the cylinder before the injector is replaced, the engine may be damaged at startup. Always check cylinders for possible coolant seepage before replacing injectors and use care to prevent coolant or fuel from contaminating the engine lubricating oil.

NOTICE:
Do not use a metal dowel to install the auxiliary injector seal, as this may damage the seal.

1. Place the auxiliary seal in the injector hole.
2. Seat it against the top of the injector tube with a 1-5/8 in. diameter wood or plastic dowel. See Figure 2-16.

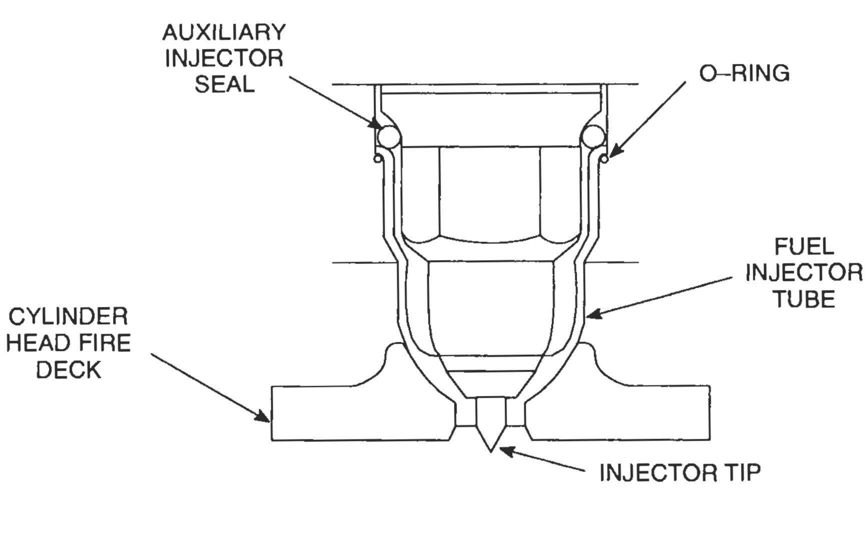


Figure 2-16 Auxiliary Injector Seal Location

2.3.5 Installation of Injector Tube and O–Ring

Perform the following steps for injector tube installation:

NOTICE:
DO NOT lubricate the outside of the injector tube or inside the cylinder head injector tube bore to facilitate installation of the tube. Lubricant may cause the tube to turn during reaming or flaring operations possibly damaging the injector tube or reamers.

1. Lubricate the blended fluorocarbon injector tube sealing O–ring with liquid hand soap.

NOTE:
This ring was formerly made of fluoroelastomer and had a blue coating for identification. It is now made of a special blended fluorocarbon material with an orange Teflon coating for identification. Former and current–design seal rings are completely interchangeable, and only the current orange–coated seal ring will be serviced.

2. Place the O–ring over the injector tube, sliding it up to the lip.
3. Install the injector tube on the injector tube installation/removal tool, J 33880–4. See Figure 2–17.

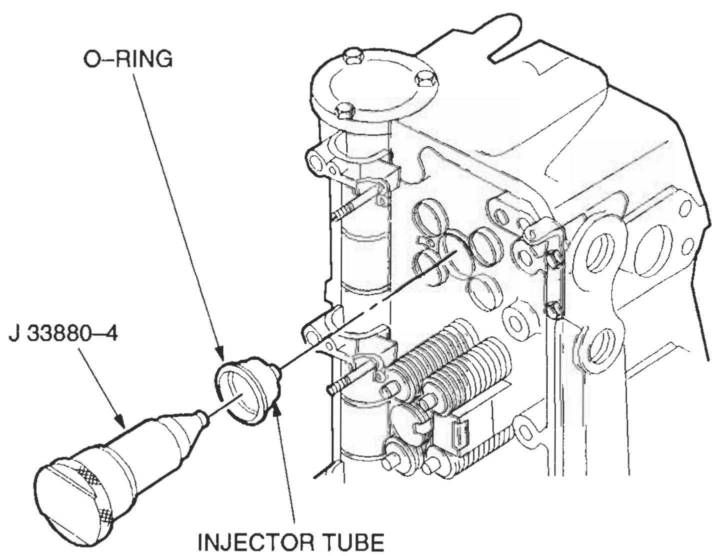


Figure 2–17 Installing Injector Tube

4. Install the injector tube installation/removal tool with tube in place, into the injector bore. Be sure the tip of the injector tube goes through the small hole in the fire deck. Tap lightly on the end of the tool, if necessary, to seat the tube.
5. Install the EUI hold–down clamp and bolt it in place over the installation/removal tool. See Figure 2–18.

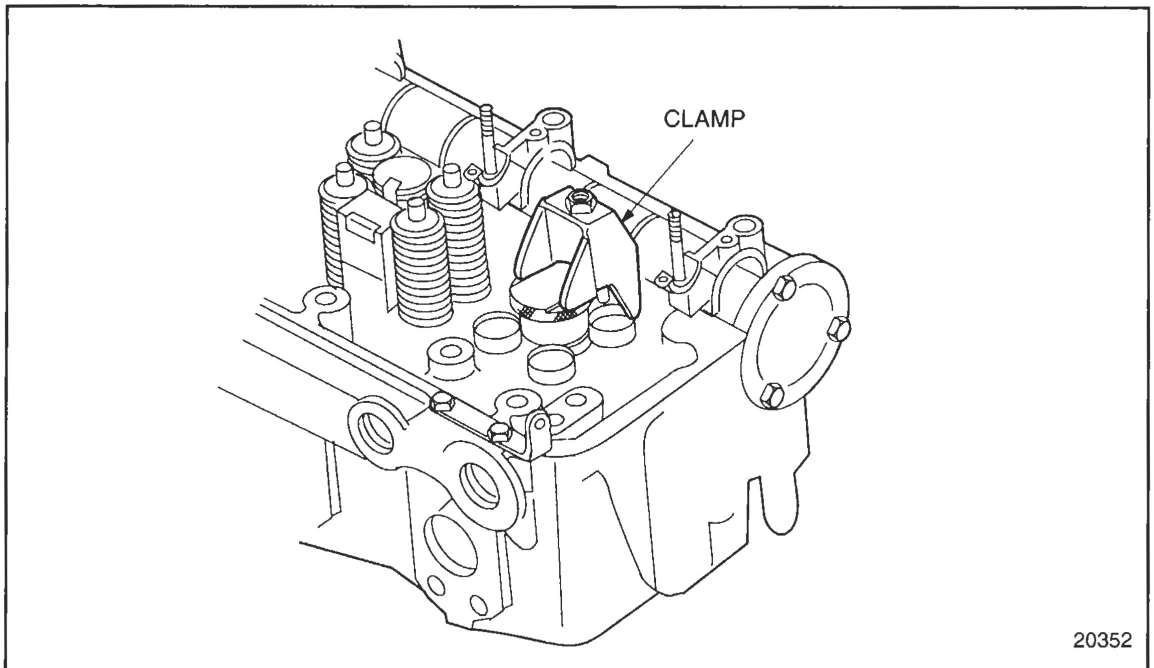


Figure 2–18 Installing Injector Hold–down Clamp

6. Torque the EUI hold–down clamp bolt 58–66 N·m (43–49 lb·ft). This will seat the injector tube at the desired depth.

After an injector tube has been installed in a cylinder head, it must be finished. For flaring injector tube, use injector tube installation, removal and refinishing tool set, J 33880. See Figure 2–19.

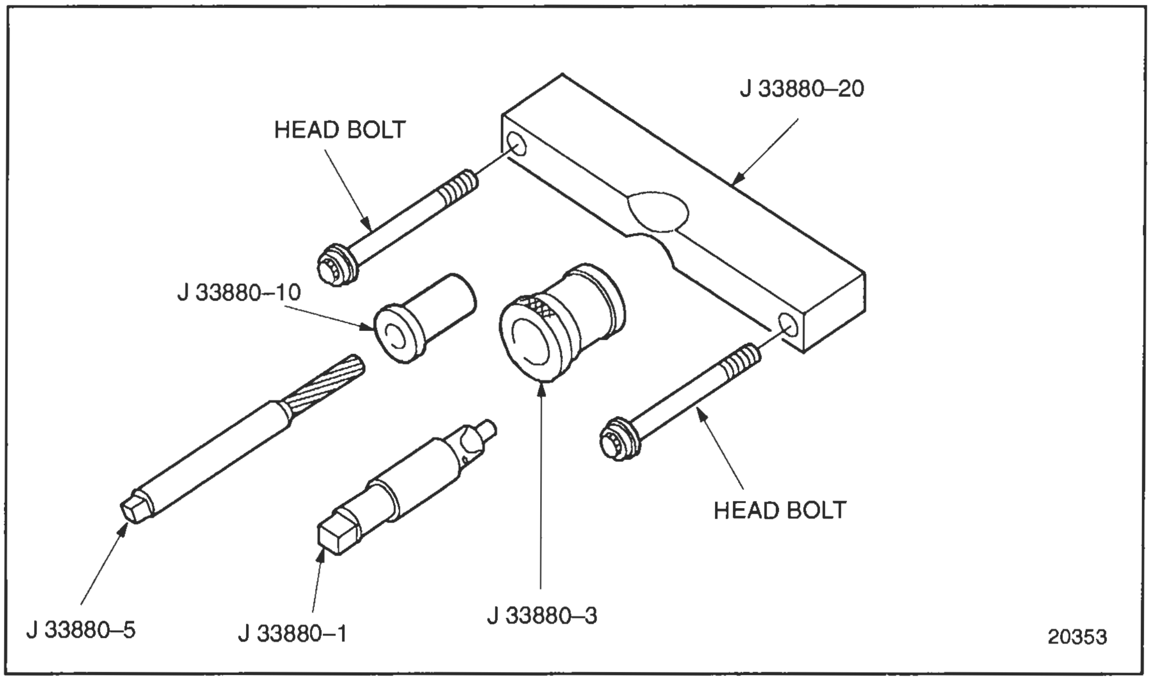


Figure 2–19 Injector Tube Installation, Removal and Refinishing

Perform the following steps for a flaring injector tube:

1. Insert the injector tube flaring tool, J 5286–6 through the small hole in the bottom of the tube, rotating to engage the threads in the installation/removal tool.
2. Using a torque wrench and 12–point, 29/32 in. socket, screw the flaring tool into the tube installation/removal tool until it begins to flare the tube. See Figure 2–20.

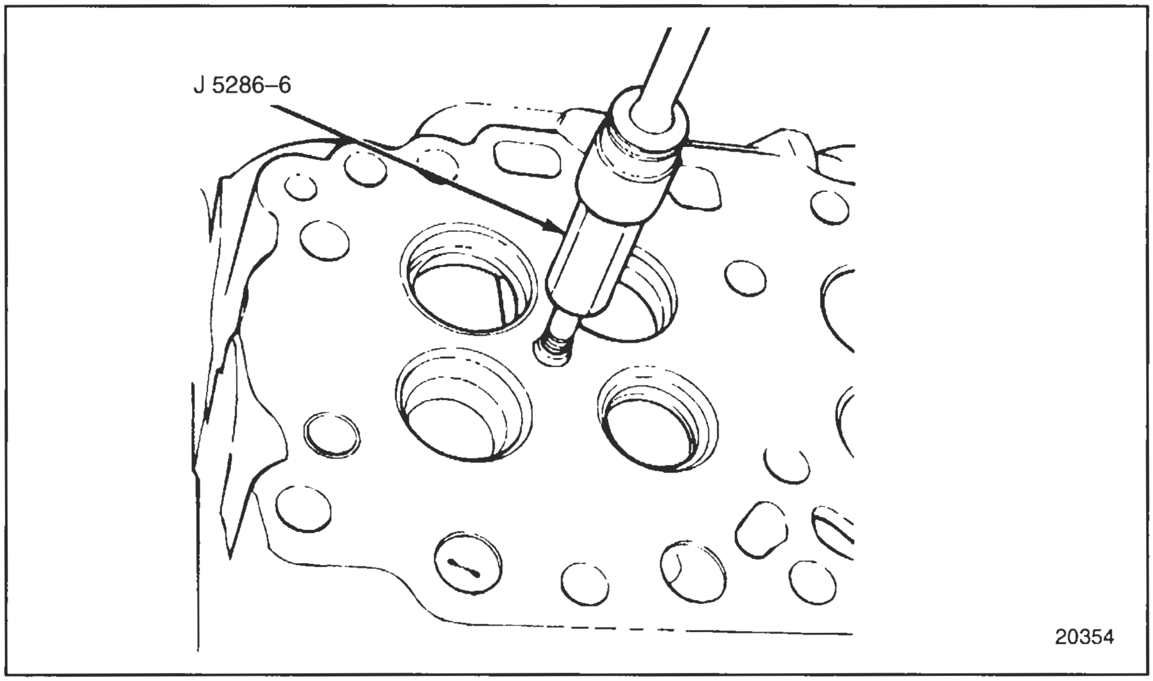


Figure 2–20 Flaring Injector Tube Tip

3. Continue to rotate the flaring tool and apply pressure to the flare end of the tube firmly against the cylinder head casting tube opening. Do not exceed 41 N·m (30 lb·ft) torque. See Figure 2–21.

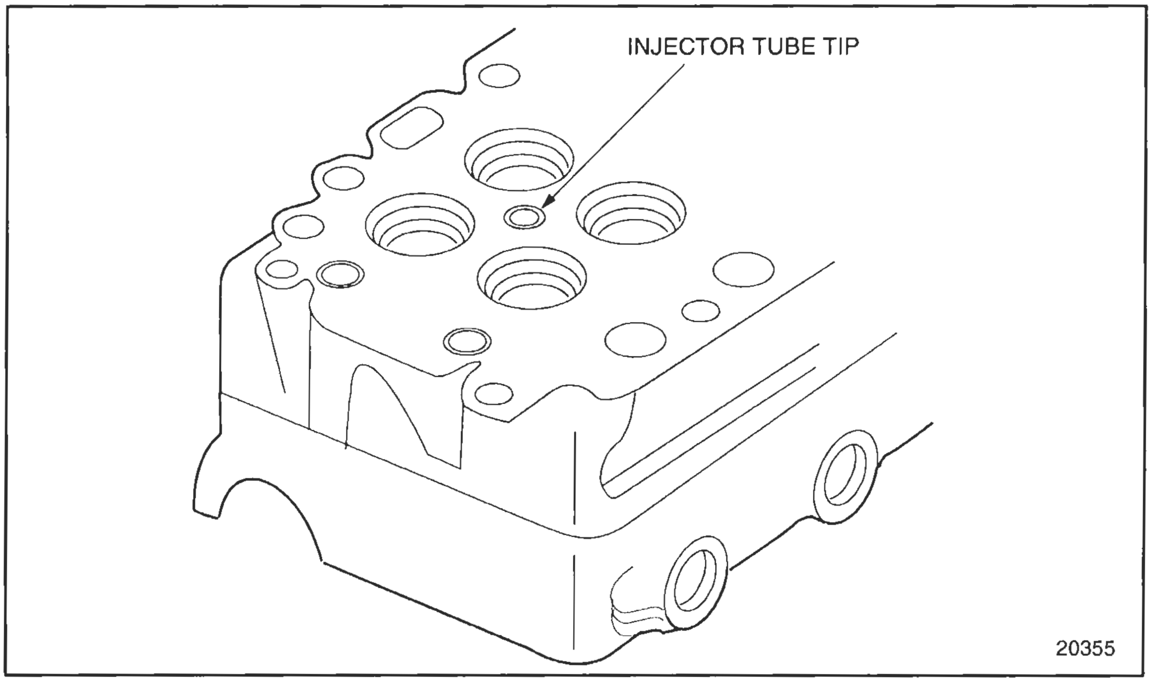


Figure 2–21 Properly Flared Injector Tube Tip

4. Remove the flaring and installation tools.

The tapered lower end of the injector tube must provide a smooth and true seat for the lower end of the injector nut to effectively seal the cylinder pressures and properly position the injector tip into the combustion chamber. To ream the injector tube, complete the following steps:

1. Install the seat reamer pilot tool, J 33880–3, into the injector bore until it contacts the cylinder head.

NOTICE:
Turn the reamer in a clockwise direction only (both when inserting and withdrawing the reamer) because movement in the opposite direction will dull the cutting edges of the flutes.

2. Install the tip reamer pilot tool, J 33880–10, into the seat reamer pilot until it bottoms.

3. Place a few drops of cutting oil on the cutting edges of the tube tip reamer tool, J 33880–5, and install it in the pilot. See Figure 2–22.

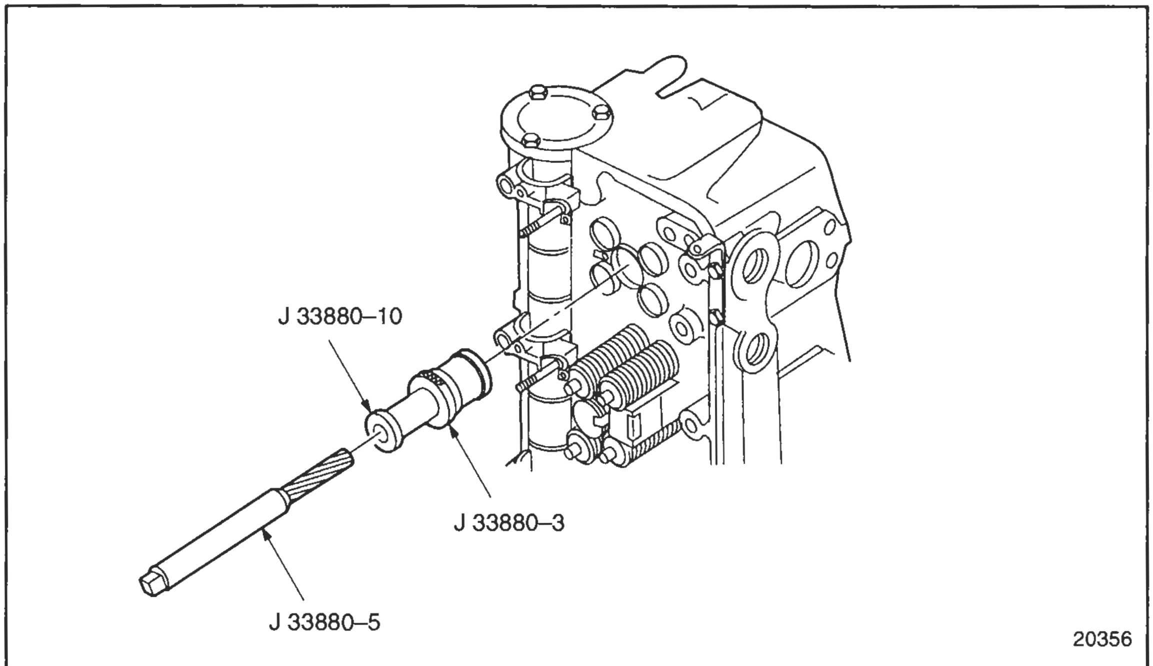


Figure 2–22 Reaming Injector Tube Tip

4. Using a speed handle with 7/16 in. socket attached, turn the tip reamer in a clockwise direction using light pressure until it goes completely through the end of the injector tube.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

5. Remove the reamer and pilot. Blow out the injector tube and tip with compressed air to remove all metal shavings.

6. Install the stop block tool, J 33880–20, to the firedeck of the cylinder head using two existing head bolts. Tighten the head bolts, but do not torque. Position the cut out portion of the stop block beneath the injector tube. See Figure 2–23.

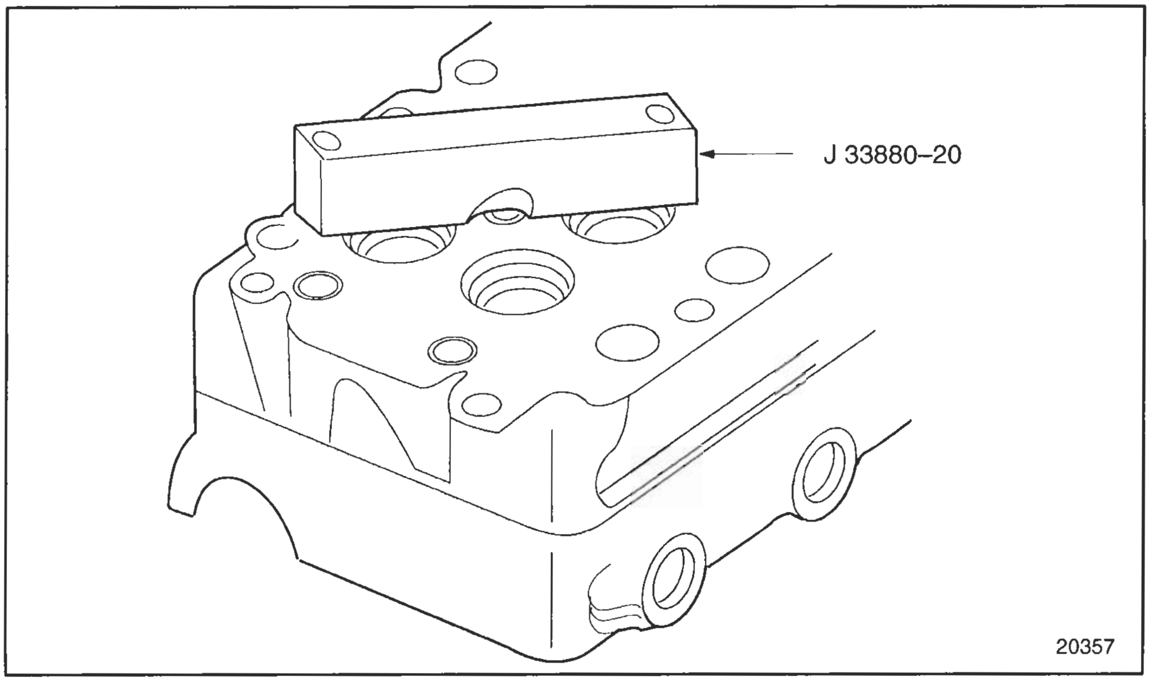


Figure 2–23 Stop Block Installed on Cylinder Head

7. Install the seat reamer pilot tool, J 33880–3, into the injector tube bore until it contacts the cylinder head.

CAUTION:

If the seat reamer is dropped into the pilot, or is allowed to strike the injector tube, this may cause chatter marks in the seat. Use extreme care when inserting the seat reamer to prevent damaging the tube.

8. Place a few drops of cutting oil on the edges of the seat reamer tool, J 33880–1, and gently place it in the pilot. See Figure 2–24.

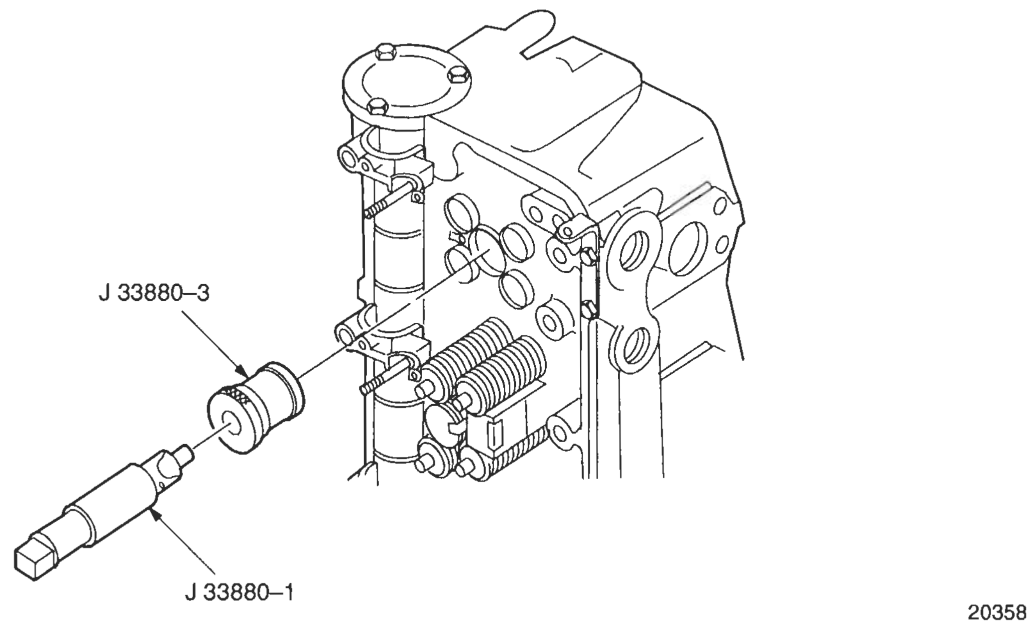


Figure 2–24 Reaming Injector Tube Seat

NOTICE:

Turn the reamer in a clockwise direction only, because movement in the opposite direction will dull the cutting edges of the flutes.

9. Using a speed handle with 15/16 in. socket attached, turn the seat reamer in a clockwise direction with light pressure. Continue until the reamer bottoms against the stop block.

10. Inspect the tube seating surface to ensure that there are no irregularities or chatter marks in the seating surface. If irregularities or chatter marks are found, remove and replace the injector tube. See Figure 2-25.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

11. Remove the reamer and pilot. Clean out the injector tube with compressed air.

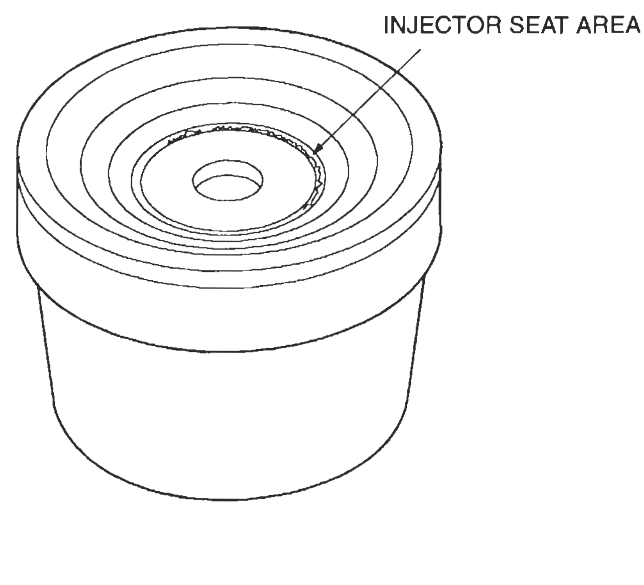


Figure 2–25 Injector Tube Seat Irregularities

12. Remove the two head bolts and stop block from the cylinder head.

13. Spot–face the injector tube as follows:

   [a] With the cylinder head firedeck in a workable position, insert the tube tip refinisher tool, J 5286–8, into the injector tube. See Figure 2–26.

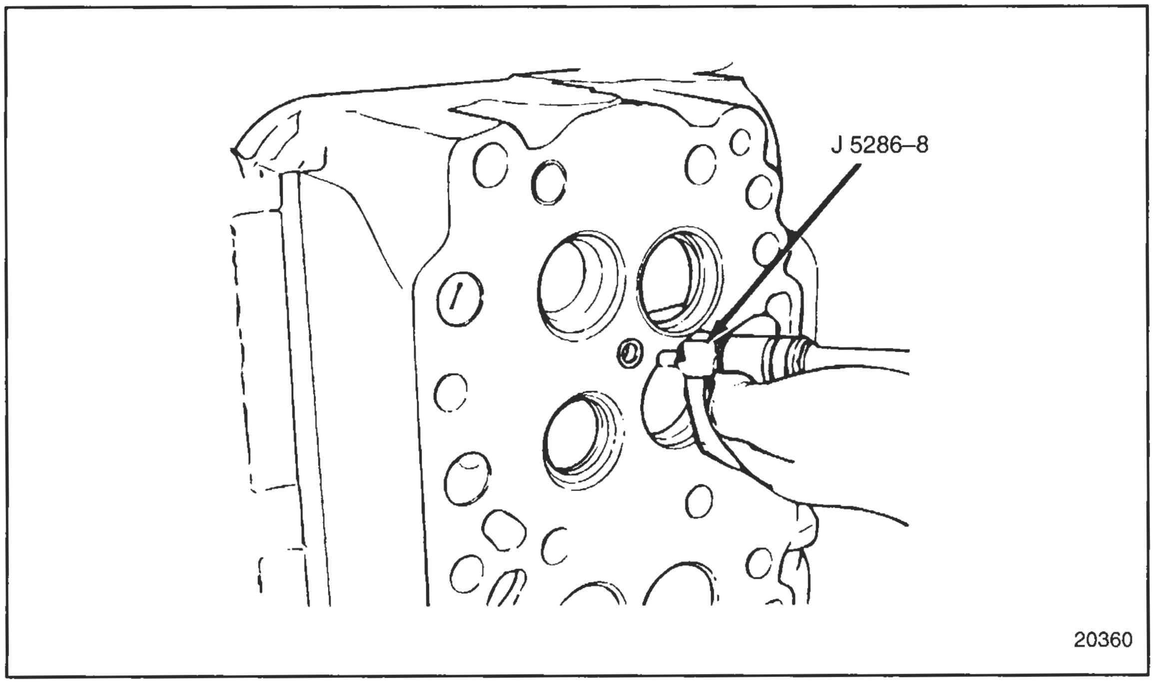


Figure 2–26 Refinishing Injector Tube Tip

   [b] Using a 12–point socket and speed handle, turn the refinisher to remove excess stock so that the lower end of the injector tube is from flush to 0.76 mm (.003 in.) below the firedeck surface of the cylinder head.

   [c] Remove the chips from the injector tube.

2.3.5.1 Check Injector Tip Protrusion

To check the injector tip protrusion:

1. Insert the seat reamer pilot tool, J 33880-3, into injector tube bore of cylinder head.
2. Insert protrusion gage tool, J 33880-7, into pilot. See Figure 2-27.

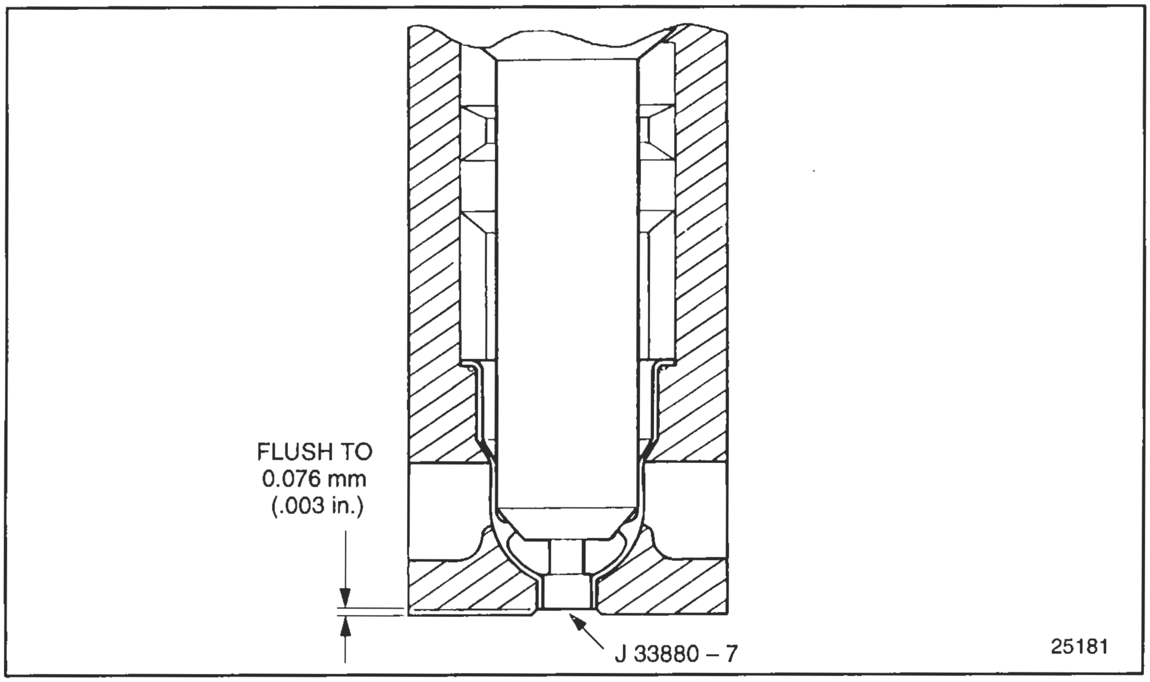


Figure 2–27 Checking Injector Tip Protrusion

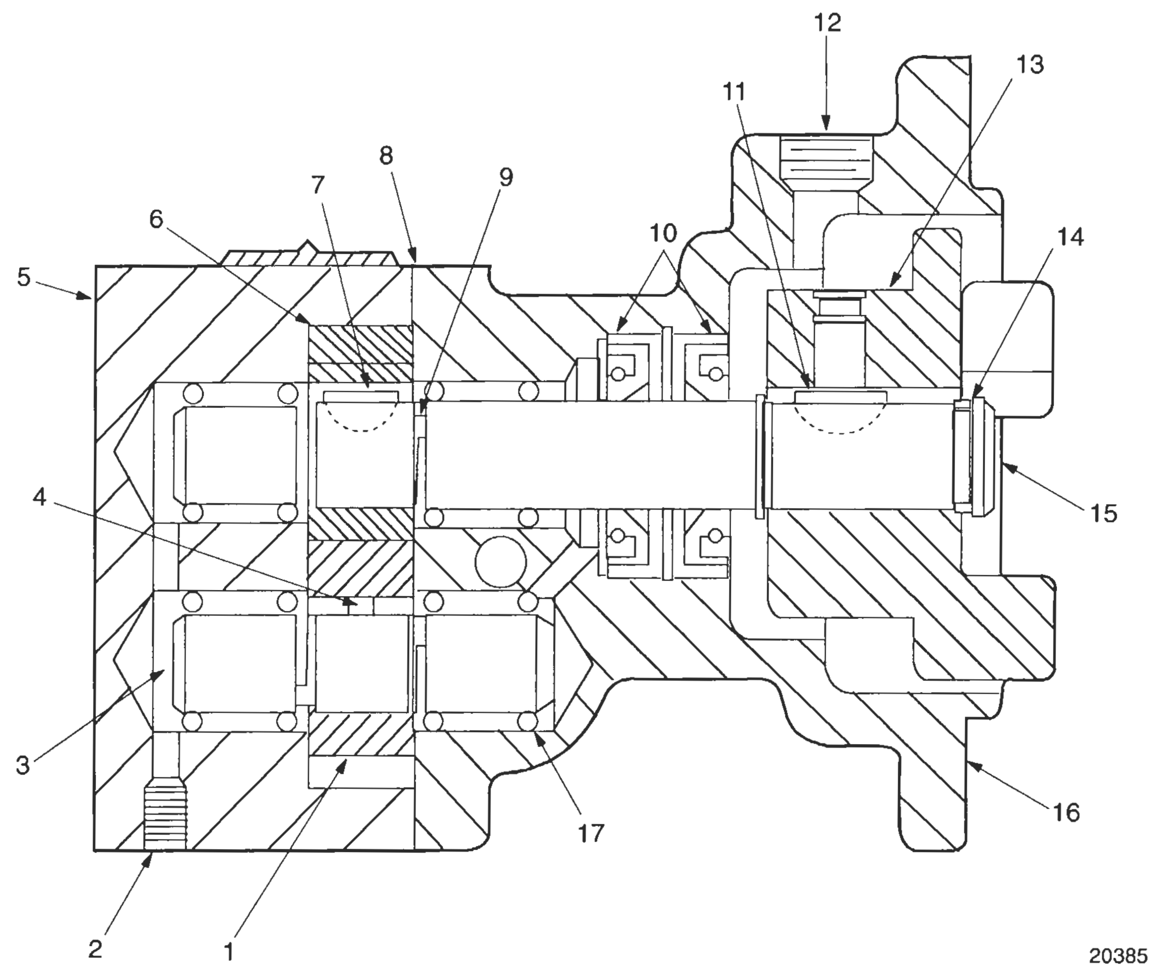
3. Check injector tip protrusion using sled gage tool, J 22273-01. Hold protrusion gage against pilot while measuring tip protrusion. This measurement should be flush to 0.076 mm (.003 in.) below the firedeck surface.

2.4 FUEL PUMP

The fuel pump system consists of the following components:

- ❑ Barnes positive displacement type fuel pump
- ❑ Air compressor drive coupling
- ❑ Gear train mounting adaptor

The positive displacement gear–type fuel pump is seen in the next illustration. See Figure 2–28.



1. Driven Gear
2. Plug
3. Driven Shaft
4. Pin
5. Cover
6. Drive Gear
7. Key
8. Gasket
9. Snap Key
10. Oil Seals
11. Key
12. Plug
13. Drive Hub
14. Snap Ring
15. Drive Shaft
16. Pump Body
17. Needle Bearing

Figure 2–28 Fuel Pump Assembly

The fuel pump transfers fuel from the supply tank to the fuel injectors. The pump circulates an excess supply of fuel through the injectors which purges the air from the system and cools the injectors. The unused portion of fuel returns to the fuel tank by means of a fuel return line.

The fuel pump is attached to either a drive assembly mounted on the rear side of the gear case, or driven off of the rear of the air compressor. See Figure 2-29.

The fuel pump cover and body are positioned by two dowels. The dowels aid in maintaining alignment between the body, cover and shafts. The mating surfaces of the pump body and cover are perfectly flat ground surfaces. A gasket is used between the cover and body.

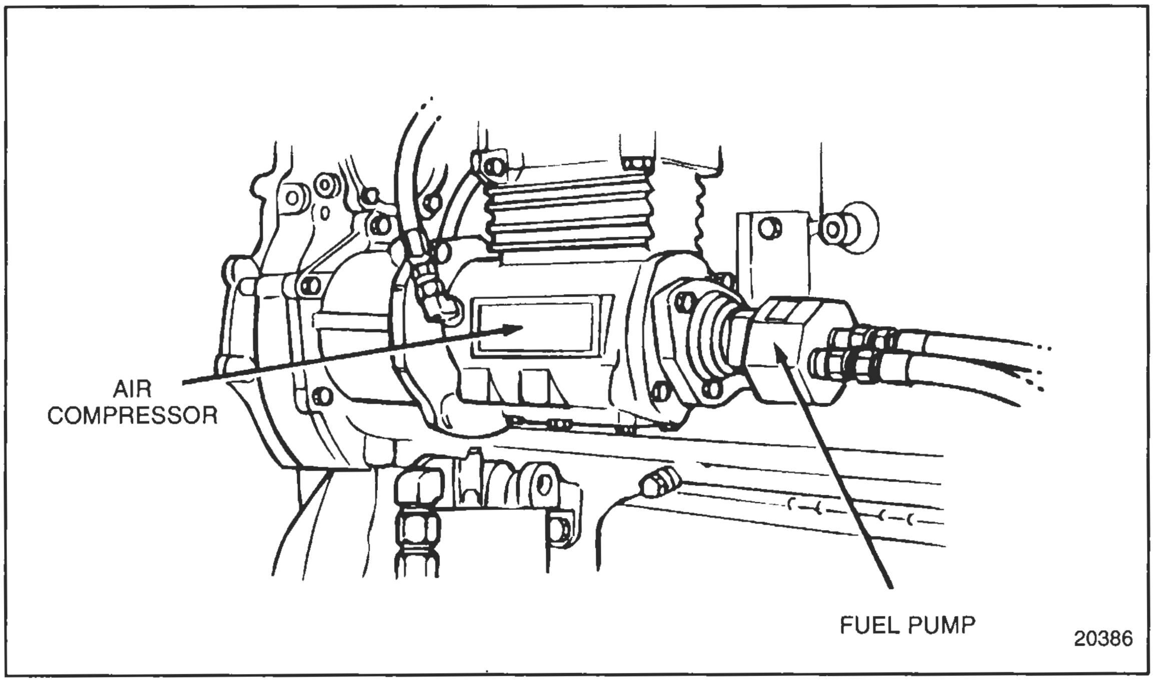
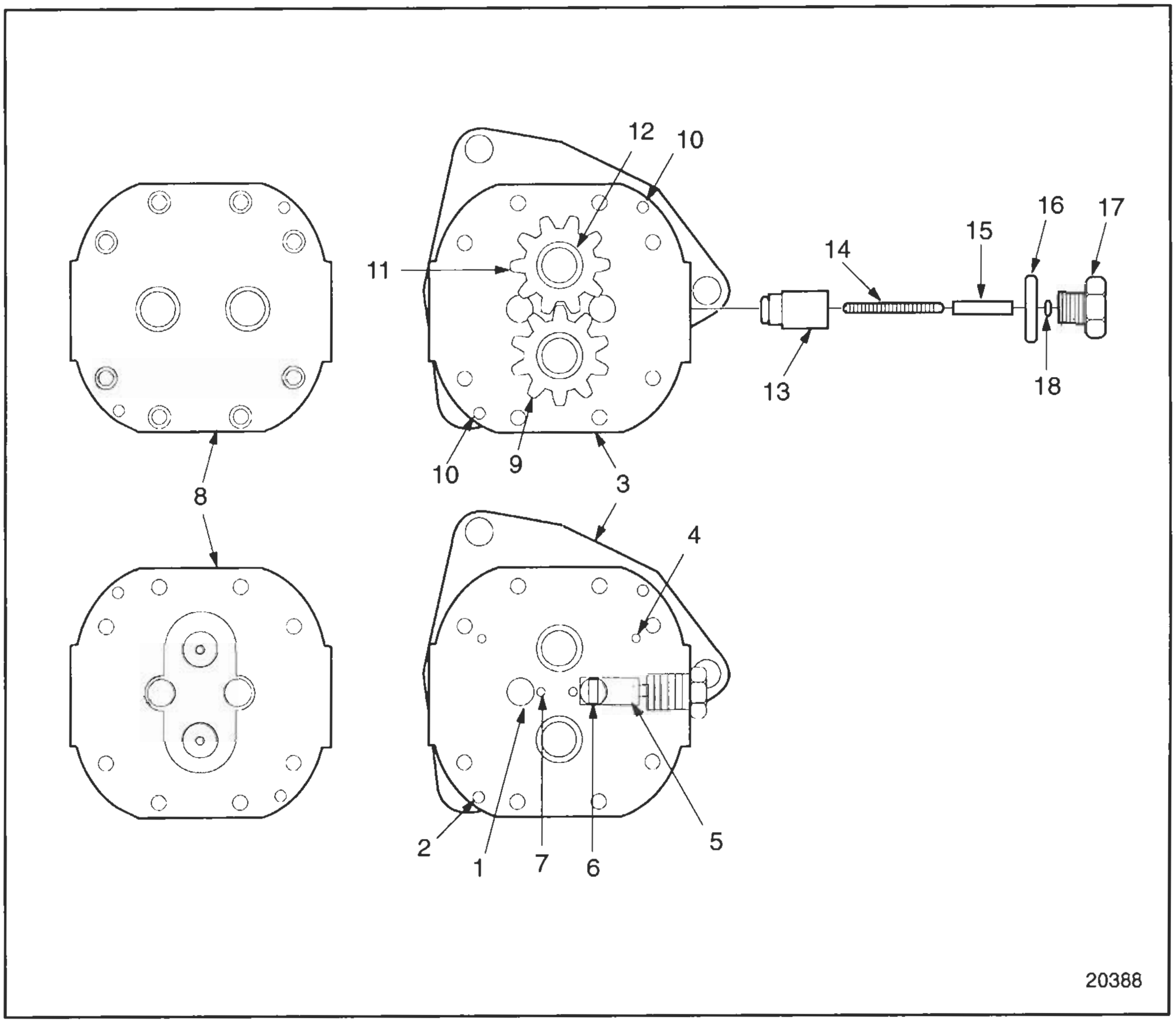


Figure 2-29 Fuel Pump Mounting

The fuel pump body is recessed to provide running space for the pump gears. Recesses are also provided at the inlet and outlet positions of the gears. The small relief valve vent (5) (see Figure 2-30) permits the fuel oil in the inlet side of the pump to lubricate the relief valve at its outer end. This eliminates the possibility of a hydrostatic lock which would render the relief valve inoperative. Pressurized fuel contacts the relief valve through the passage to head of the relief valve (1) and provides for relief of excess discharge pressures. Fuel re-enters the inlet side of the pump through the passage to head of the relief valve (6) when the discharge pressure is great enough to move the relief valve back from its seat. Part of the relief valve may be seen through the passage to head of the relief valve (6). The gear teeth vent cavity (7) provides escape for the fuel oil that is squeezed out of the gear teeth as they mesh together on the discharge side of the pump. Otherwise, fuel trapped at the root of the teeth would tend to force the gears apart, resulting in undue wear on the gears, shafts, body, and cover. See Figure 2-30.



1. Passage to Head of Relief Valve–Pressure Side
2. Dowel Hole
3. Body
4. Oil Seal Vent to Suction Side
5. Relief Valve Vent to Suction Side
6. Passage to Head of Relief Valve–Suction Side
7. Gear Teeth Vent Cavity
8. Cover
9. Drive Gear
10. Dowel
11. Drive Gear
12. Drive Shaft Gear
13. Relief Valve
14. Spring
15. Pin
16. O–ring
17. Plug
18. Spacer

Figure 2–30 Fuel Pump

Two oil seals are pressed into the bore in the flanged side of the pump body to retain the fuel oil in the pump and the lubricating oil in the fuel pump drive and gear case. The oil seal vent (4) (see Figure 2–30) serves as a vent passageway in the body, between the inner oil seal and the suction side of the pump, which prevents building up any fuel oil pressure around the shaft ahead of the inner seal. The oil seals are installed with the lips of the seals, see Figure 2–31.

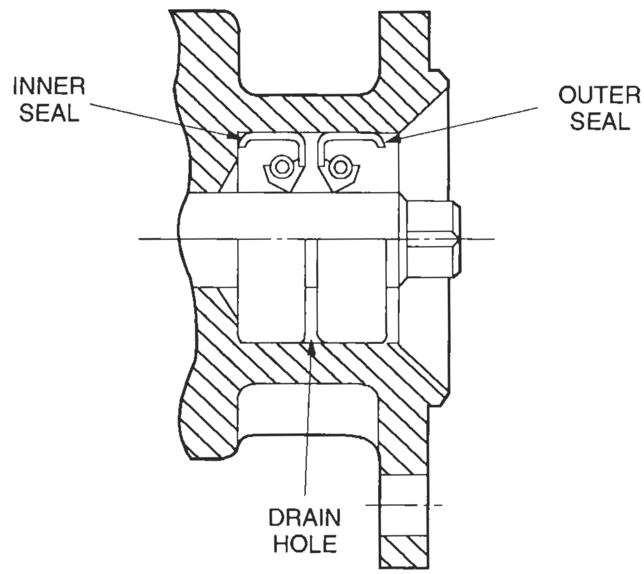


Figure 2–31 Fuel Pump Oil Seal Arrangement

Some fuel oil seepage by the fuel pump can be expected with a running engine and immediately after an engine has been shut down. This is especially true with a new fuel pump new pump seals or both, as the seals have not yet conformed to the pump drive shaft. Fuel pump seals will always allow some see page. A drain hole in the pump body is provided to prevent fuel oil from being retained between the seals. Excessive fuel retention between the seals could provide enough pressure to cause engine oil dilution by fuel; therefore, drainage of the excess fuel oil is mandatory. However, if leakage exceeds one drop per minute, replace the seals.

A spring–loaded relief valve incorporated in the pump body normally remains in the closed position, operating only when pressure on the outlet side (to the fuel filter) reaches approximately 448 kPa (65 lb/in.^{2}). The drain hole should be checked for plugging at normal scheduled maintenance.

In operation, fuel enters the pump on the suction side and fills the space between the gear teeth that are exposed at that instant. The gear teeth then carry the fuel oil to the discharge side of the pump and as the gear teeth mesh in the center of the pump, the fuel is forced out the outlet cavity. Since this is a continuous cycle and fuel is continually being forced into the outlet cavity, the fuel flows from the outlet cavity into the fuel lines and through the engine fuel system under pressure.

The pressure relief valve relieves the discharge pressure by bypassing the fuel from the outlet side of the pump to the inlet side when the discharge pressure reaches approximately 448 to 517 kPa (65 to 75 lb/in.^{2}).

The fuel pump should maintain the fuel pressure listed in Table 11–2.

2.4.1 Repair or Replacement of Fuel Pump

To determine if repair or replacement of the fuel injector tube is necessary. See Figure 2-32.

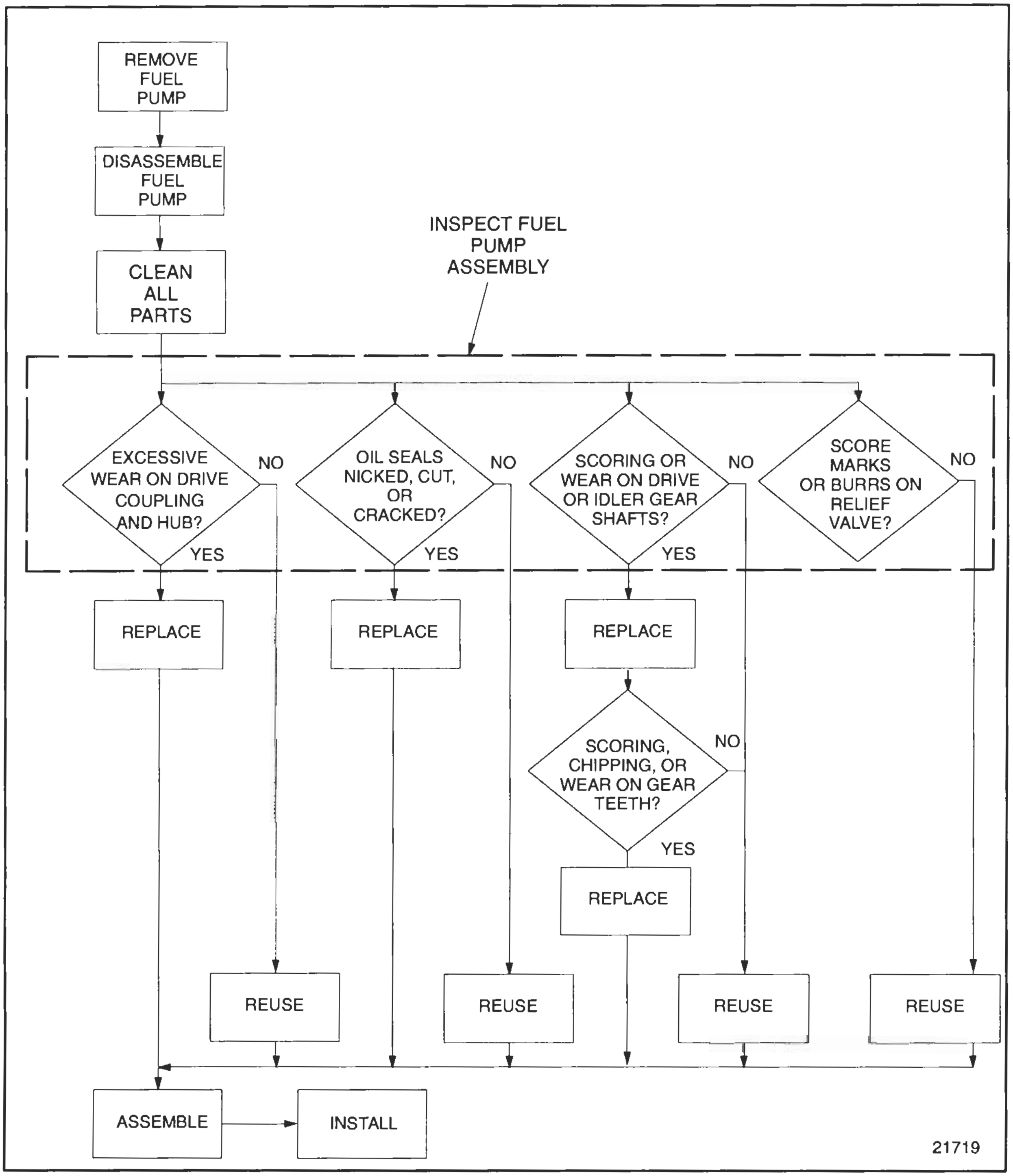


Figure 2–32 Flowchart for Repair or Replacement of Fuel Pump

2.4.2 Cleaning and Removal of Fuel Pump

Perform the following steps for fuel pump removal:

1. Disconnect the fuel lines from the inlet and outlet openings of the fuel pump.
2. Remove the three fuel pump attaching bolts and withdraw the pump from the mounting adaptor on the gear case or air compressor.
3. Check the drive coupling and if broken or worn, replace it with a new coupling.

2.4.3 Fuel Pump Disassembly

Perform the following steps for fuel pump disassembly:

1. With the fuel pump removed from the engine, clamp the pump in a bench vise equipped with soft jaws.
2. Remove fuel inlet and outlet fittings from fuel pump cover.
3. Remove access hole plug.
4. Use snap ring pliers, J 4880, and remove outer drive hub positioning snap ring.

NOTE:
It may be necessary to rotate the drive hub and shaft to align the set screw with access hole.

5. Working through access hole, loosen but do not remove set screw securing drive hub to drive key.
6. Slide drive hub off shaft and remove drive key from shaft.
7. Use snap ring pliers, J 4880, and remove inner drive hub positioning snap ring.

8. Position pump on holding fixture, J 38767–1, hub side down. See Figure 2–33.

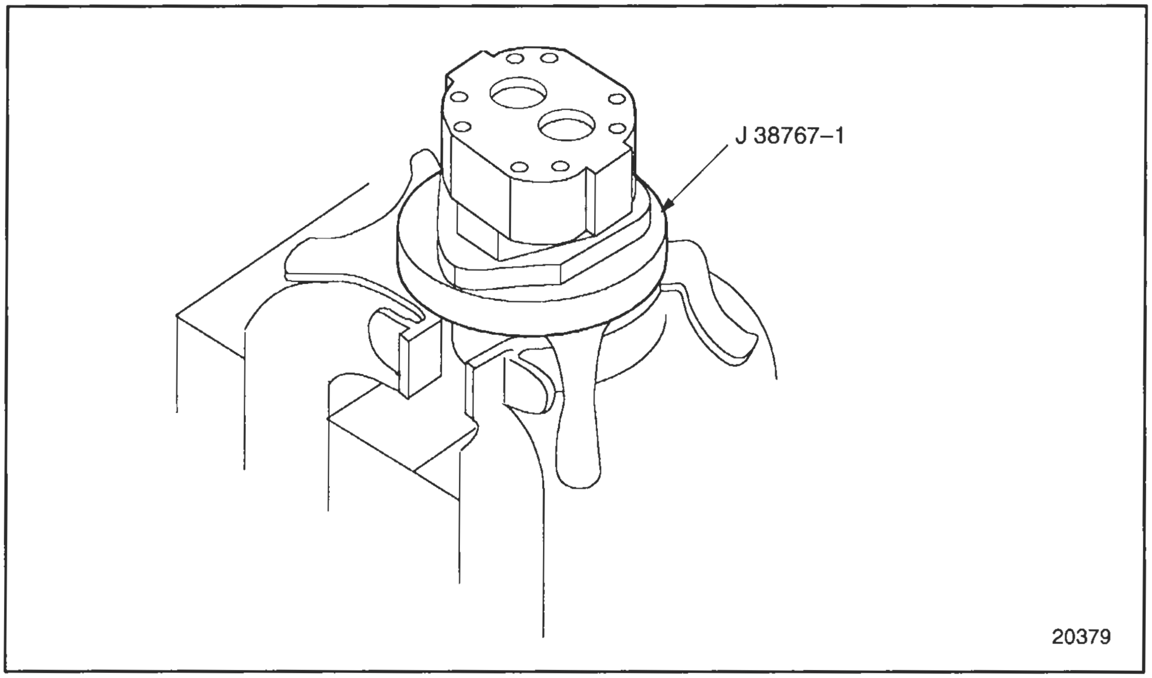


Figure 2–33 Fuel Pump Holding Fixture

9. Using a No. E–8 torx socket, J 25359–11, remove eight (8) bolts securing the pump cover to body.

NOTE:
Note the color of the foil gasket, gold or silver. If the pump is reassembled, the same color foil gasket must be used. The gaskets are of different thickness and establish correct internal clearance.

10. Separate the pump cover from the body by lifting it off the shafts and dowels. Remove and discard the foil gasket between the cover and body.

NOTE:
When the drive shaft is removed from the pump, the oil seals must be replaced.

11. Withdraw the driven shaft and drive shaft and gear assemblies from the pump body.
12. Remove the C–clips that retain the gears on the shafts taking care not to lose the drive pin from the drive shaft or the key from the drive shaft.

13. Remove the gears from the shafts.

NOTE:
When the drive shaft is removed, the drive shaft needle bearing assembly in the pump body must also be removed to allow installation of the oil seal protector used during reassembly.

14. Use needle bearing remover, J 33853, with slide hammer and remove the needle bearing assemblies from the pump body and cover. See Figure 2–34.

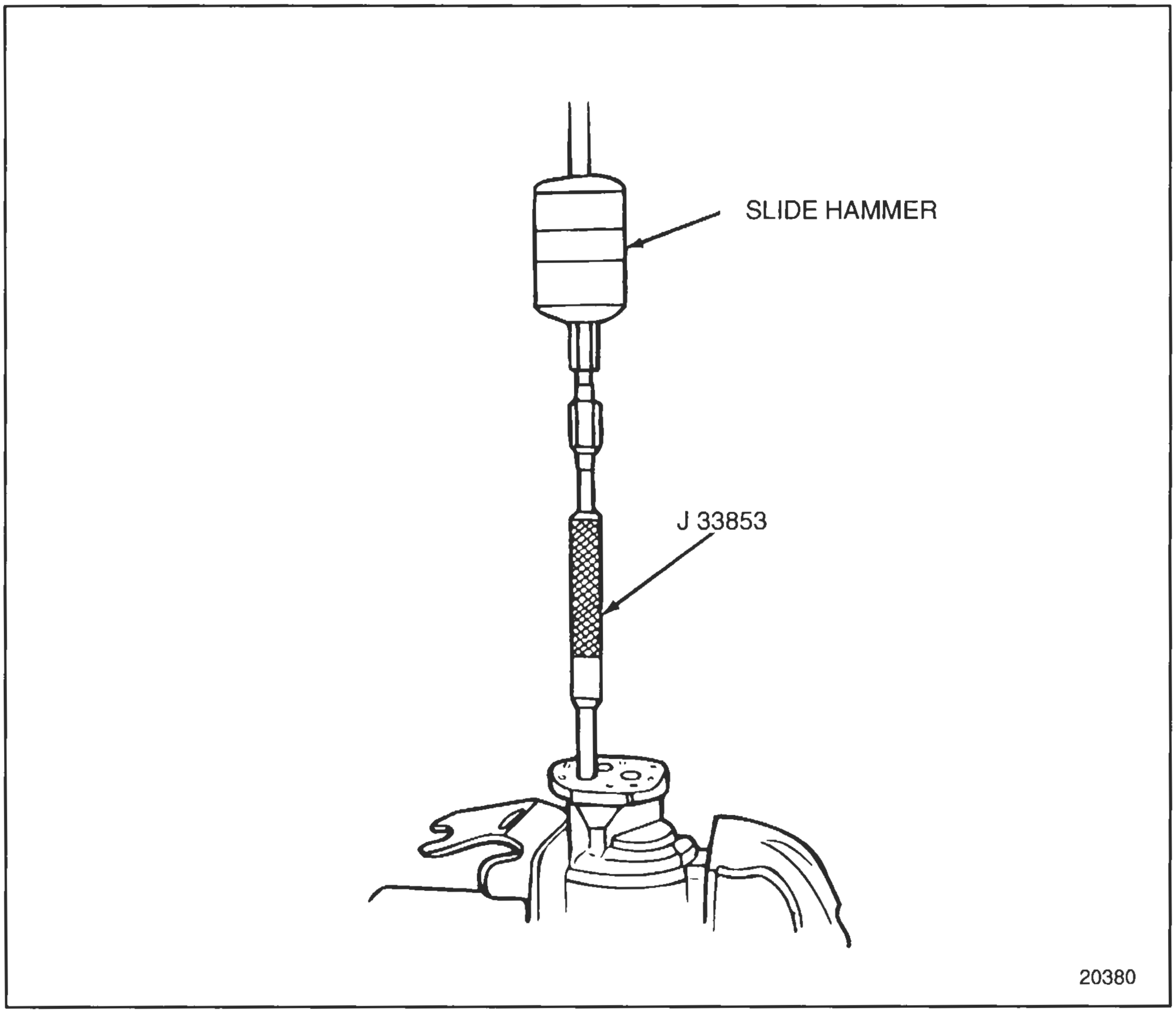


Figure 2–34 Needle Bearing Removal

15. Position pump on fixture, J 38767–1, and insert lip of seal remover, J 1508–13, between the inner and outer oil seals. Tap the tool with a light hammer to drive the outer seal out of the pump body. See Figure 2–35. Discard the seal.

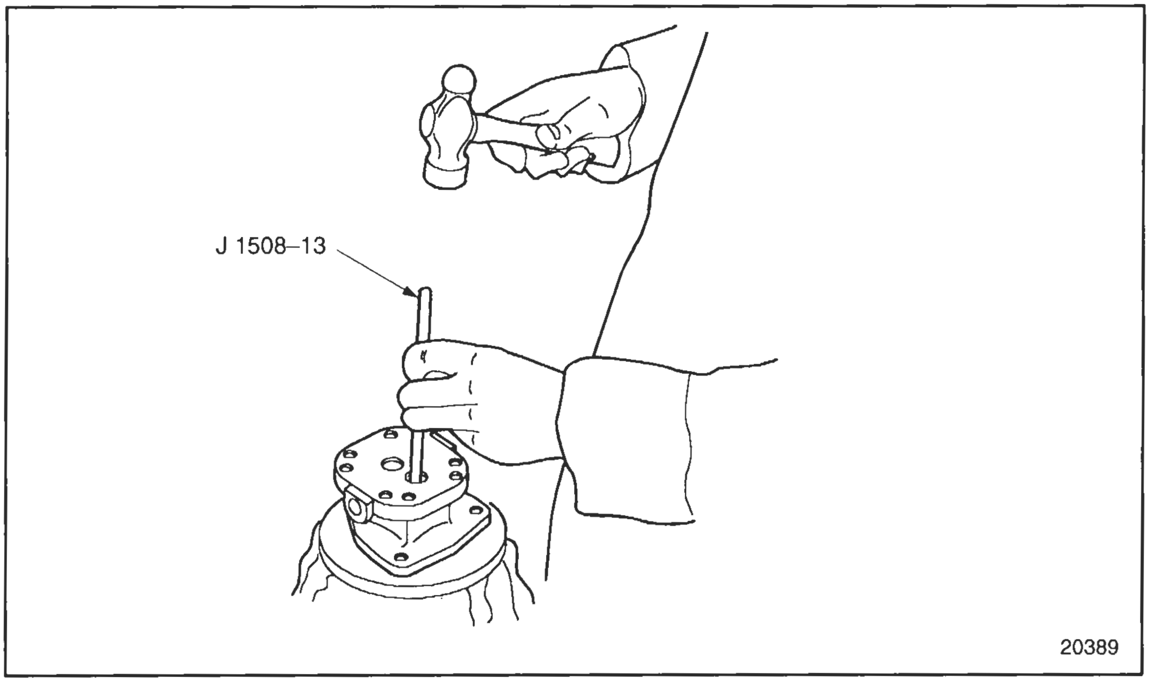


Figure 2–35 Oil Seal Removal

16. Repeat the process removing the inner seal by placing the tool lip against the inside of the seal case. Discard the seal.
17. Unscrew and remove the relief valve cover and remove the relief valve plunger, spring and pin from the bore.
18. Remove the spacer from the relief valve cover.
19. Remove and discard the O–ring seal under the head of the cover.

2.4.3.1 Cleaning and Inspection

All parts must be cleaned with clean fuel oil, before inspection.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

Dry the parts with compressed air.

Inspect the drive coupling and hub for wear or damage. Replace as necessary.

Oil seals, once removed, must be discarded and replaced with new seals. Oil seals must be removed whenever the fuel pump drive shaft is withdrawn. Oil seals must be free of nicks, cuts, or cracks.

Inspect the drive and idler gear shafts for scoring or wear. Replace shafts as necessary. If drive shaft is grooved from contact with oil seals, replace the shaft.

Check the gear teeth for scoring, chipping or wear. If necessary, replace the gear.

The relief valve must be free of score marks and burrs. If the relief valve is scored and cannot be cleaned up with fine emery cloth, it must be replaced.

2.4.4 Fuel Pump Assembly

Perform the following steps for fuel pump assembly:

1. Lubricate the lips of the oil seals and pilot of oil seal installer, J 1508–8, with a light film of clean engine oil.
2. Place oil seal adaptor, J 34158, on the pilot with the wide end of the adaptor against the installer handle.
3. Place oil seal on installer pilot with seal case against the adaptor. To insure proper assembly, seals must be installed in the proper location. See Figure 2–31.

4. Support the pump body on wood blocks, hub side up, and insert the pilot into the shaft bore positioning the seal on the bore. Use a light hammer and drive the seal into the bore until the adaptor is bottomed against the pump body. See Figure 2-36.

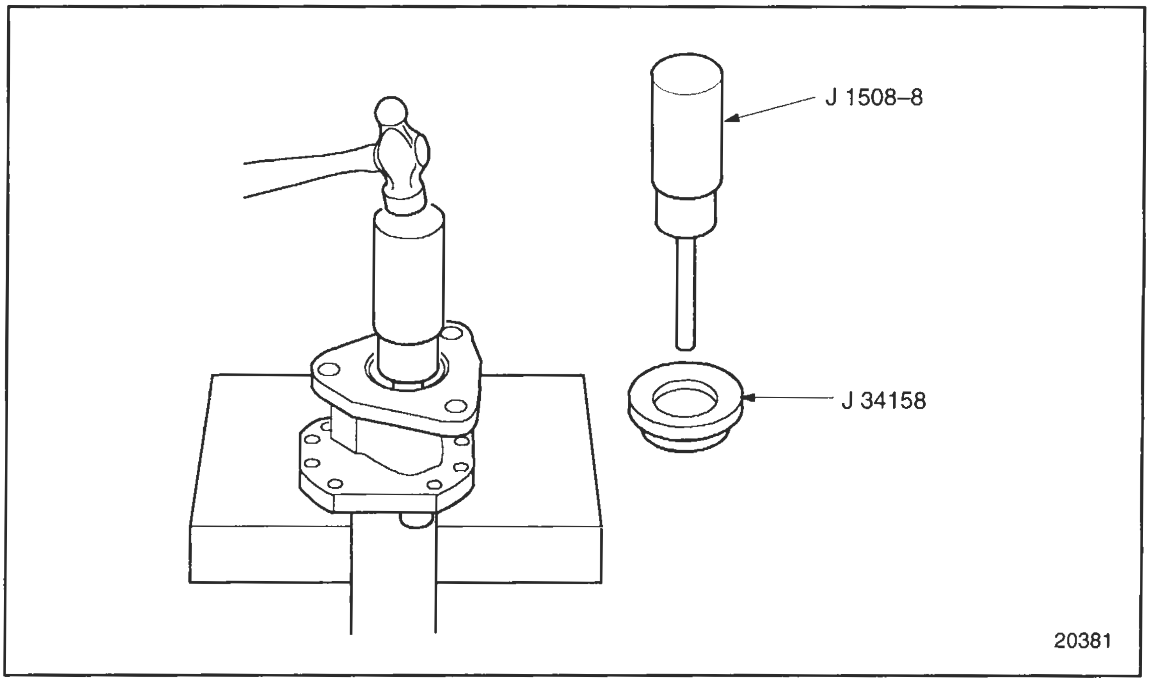


Figure 2-36 Installing Inner Oil Seal

5. Remove the installer and reverse the adaptor placing the narrow end against the installer handle. See Figure 2-37.

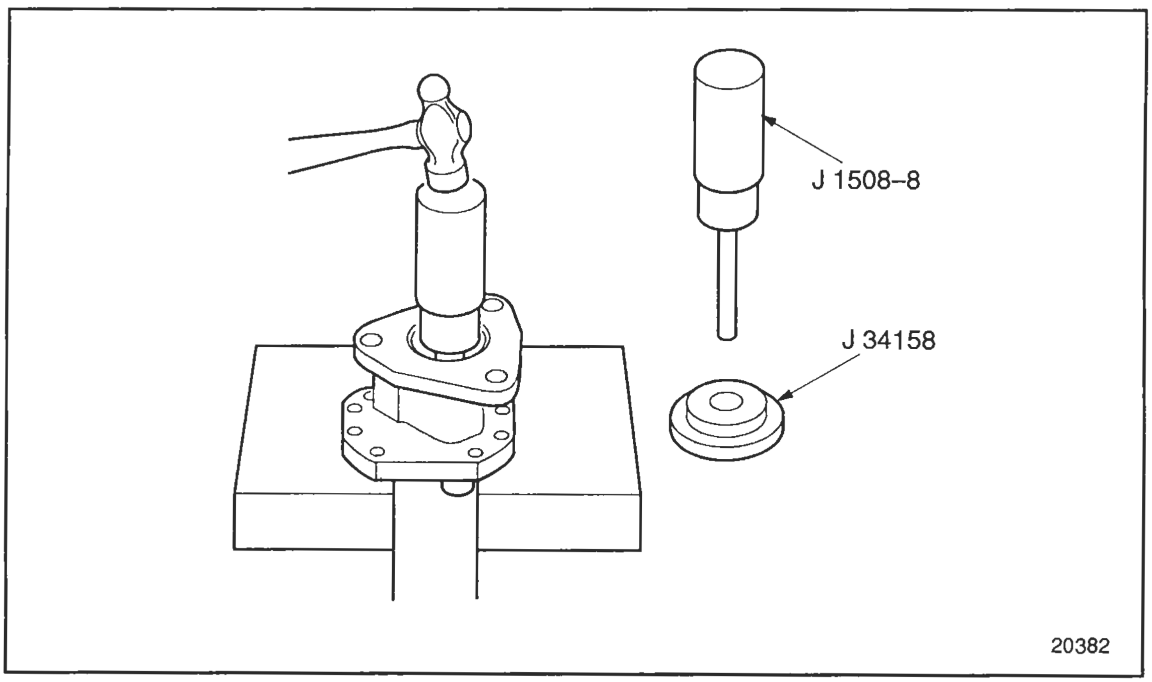


Figure 2-37 Installing Outer Oil Seal

6. Place a second seal on the installer pilot with the seal case faced away from the adaptor.
7. Carefully reinsert the installer pilot through the inner seal and position the second outer seal on the bore. Use a light hammer and drive the seal into the bore until the adaptor is bottomed against the pump body.
8. Press a fuel pump gear positioning C–clip directly into inner groove of fuel pump drive shaft opposite the drive hub end of the shaft.
9. Install drive key in slot on the drive shaft and slide the gear on the shaft indexing the keyway in the gear with the key.
10. Press a second C–clip directly into the groove behind the gear to retain it in position.
11. As the driven shaft is reversible, press a C–clip directly into either groove on the shaft.
12. Insert driven gear pin into its hole in the driven shaft with the square head of the pin parallel to the shaft. Slide the gear on the shaft indexing the keyway in the gear over the square head of the pin.
13. Press a second C–clip directly into the groove behind the gear to retain it in position.

NOTE:
The bearing numbers should always be against the tool during installation.

14. With the pump cover on a bench, inside face up, position a new roller bearing assembly on bearing installer, J 33854, with the bearing numbers against the installer. Position the bearing carefully on a shaft bore in the cover and with a light hammer drive the bearing into the bore until the installer is flush against the cover surface. See Figure 2–38. Repeat the procedure, installing a new bearing assembly in the remaining shaft bore.

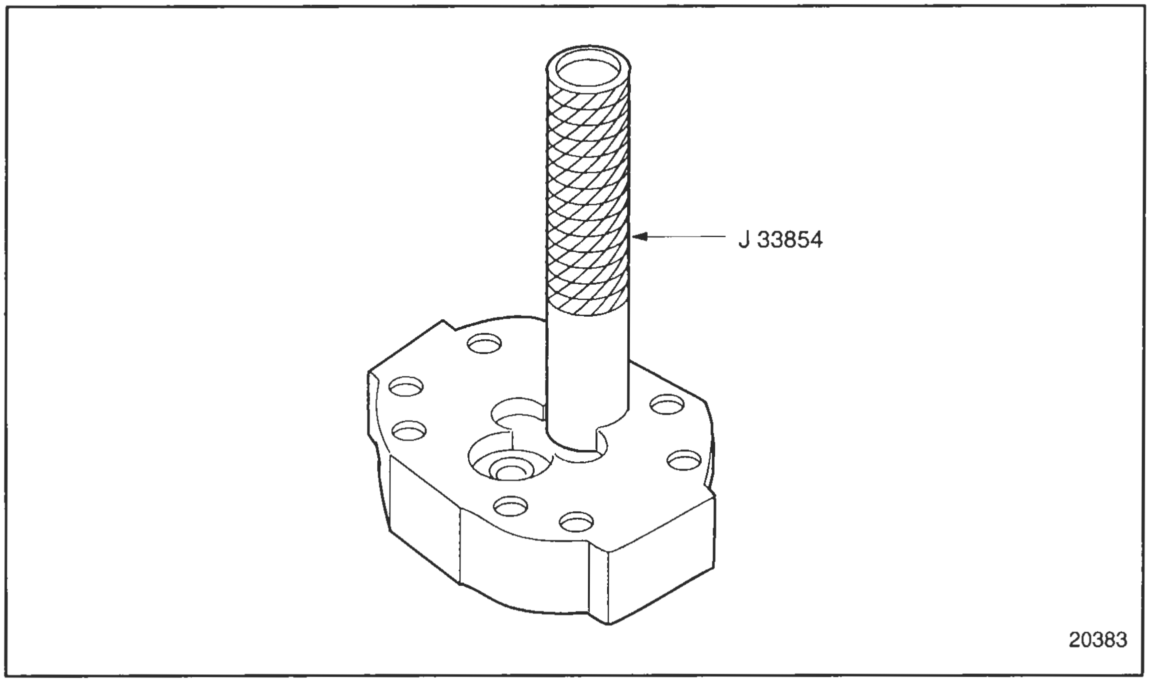


Figure 2–38 Bearing Assembly Installation

NOTE:
Do not install a needle bearing assembly in the drive shaft bore until all other needle bearings have been installed and the oil seal protector has been positioned in the seals.

15. Position the pump body on a bench, hub side down, and following the same bearing installation procedure, install a new needle bearing assembly in the driven shaft bore in the body.

NOTICE:
The seal protector must remain in place on both seals during installation of the needle bearing assembly in the drive shaft bore. If the protector is allowed to come out before the drive shaft is installed, the bearing must be removed and discarded and the protector reinstalled. The protector will be pushed out during drive shaft installation.

16. With the pump body on a bench, hub side down, lubricate the outside of seal protector, J 33021-A, with clean engine oil. Install the solid end of the protector down through both seals until it contacts the bench. See Figure 2-39. Approximately 3 mm (1/8 in.) of the open end of the protector should remain above the inner seal.

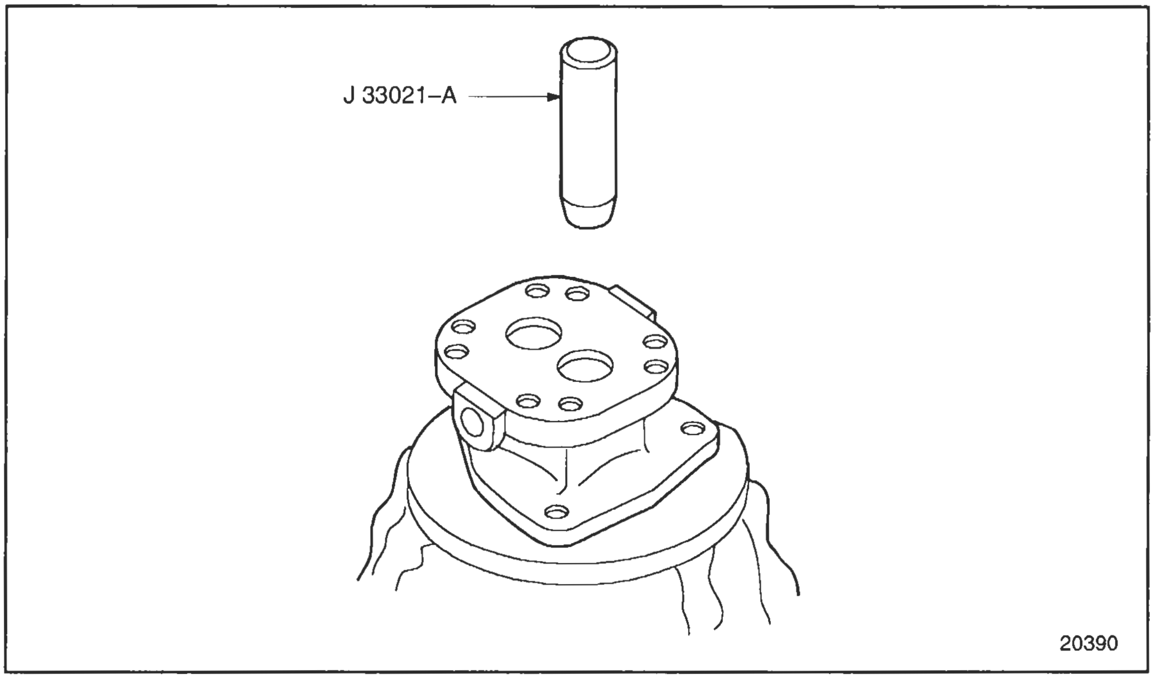


Figure 2–39 Seal Protector Installation

17. Install a new needle bearing assembly in the drive shaft bore. See Figure 2–40.

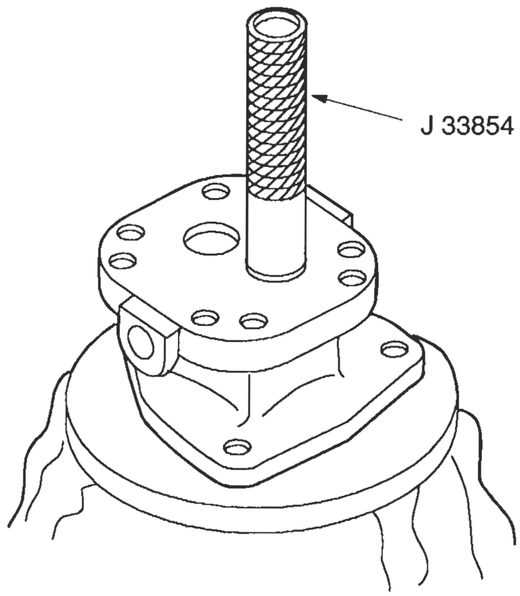


Figure 2–40 Drive Shaft Bearing Installation

18. Carefully insert the drive hub end of the drive shaft through the needle bearing assembly and into the seal protector. Ensure the shaft is fully seated in the seal protector.
19. Hold the shaft down in the seal protector and lift the pump body up against the gear. With the gear in contact with the pump body, lift the body and remove the seal protector from the drive shaft.

NOTE:
Hold the shaft in position with the gear against the pump body while handling to ensure the drive hub snap ring grooves do not contact the oil seals.

20. Position the pump body on the holding fixture, J 38767–1, hub side down.

NOTE:
When assembling pump, always use the same color foil gasket that was originally installed. Listed in Table 2–1. If color unknown, measure the depth of the gear cavity in the pump cover and install the required gasket.

Gear Cavity Depth	Color Gasket Used
.24885–.24905 in. (6.320–6.325 mm)	Blue
.24906–.24925 in. (6.326–6.331 mm)	Amber
.24935–.24955 in. (6.333–6.338 mm)	Gold
.24956–.24975 in. (6.339–6.344 mm)	Silver

Table 2–1 Color vs. Gear Cavity Depth Chart

21. Place a new foil gasket on the face of the pump. With a finger tip, carefully smooth the gasket against the face to ensure there are no wrinkles, creases or bubbles. If present, and they cannot be removed with the finger, remove the gasket and repeat the procedure.
22. Carefully insert the driven shaft and gear assembly in the needle bearing in the pump body.

NOTE:
When positioning the cover, the fuel inlet (stamped on cover) must be on the side of the relief valve bore in the pump body.

23. Position the needle bearing assemblies in the pump cover on the ends of the driven and drive shafts and slide the cover against the pump body.
24. Install eight (8) cover retaining bolts. Use No. E–8 torx socket, J 25359–11, and tighten bolts to 12–16 N·m (9–11 lb·ft).

NOTE:
As the outside of the pump body and cover are not machined and to prevent possible distortion, be sure that only the pump cover is gripped and that the vise jaws do not contact both body and cover.

25. Clamp the fuel pump cover in a soft jawed vise with the relief valve bore in the pump body up.
26. Lubricate the relief plunger with clean engine oil and insert the plunger into the bore with the hollow end up. Insert the relief spring inside the plunger and the pin inside the spring.
27. Install the spacer in the bottom of the spring seat in the cover and install a new O–ring seal under the head of the cover. Thread the cover into the pump body and tighten to 8–14 N·m (6–10 lb·ft).
28. Place the pump assembly on a bench, hub side up. Coat the surface of the outer seal with a small amount of lithium base all purpose grease.
29. Use snap ring pliers, J 4880, and install inner drive hub positioning snap ring in its groove in the shaft.
30. Remove the set screw from the drive hub and apply one drop of Loctite 242 (or equivalent) to the threads and reinstall the set screw two or three turns.

31. Install the hub drive key in the groove on the shaft and slide the hub on the shaft indexing the keyway in the hub with the key in the shaft.
32. Use snap ring pliers and install outer hub retaining snap ring in groove.
33. Rotate the drive shaft and hub to align the hub set screw with the access hole in the pump body. Tighten the set screw to 3.8 N·m (2.8 lb·ft).
34. Install access hole plug.
35. Install fuel inlet and outlet fittings in the pump cover.

2.4.5 Installation of Gear Train Driven Fuel Pump

Install the fuel pump as follows:

NOTICE:
It may be necessary to use a brass hammer or fiber mallet to seat the drive assembly. Be careful not to damage the O–ring on installation.

1. Install the drive assembly on the gear case.
2. Install the fuel pump drive bolts and torque to 30–34 N·m (22–25 lb·ft) using the torque pattern.
3. Install the fuel pump.
4. Install any other components that were removed for this procedure.
5. Start the engine and check for leaks.

2.4.6 Installation of Air Compressor Driven Fuel Pump

Perform the following steps for fuel pump installation:

NOTE:
New fittings have sealant already applied. If reusing fittings, coat the threads lightly with Loctite Pipe Sealant, J 26558–92, or equivalent before installing. To prevent sealant from entering fuel system, do not apply it to the first two (2) threads of the fitting. Do not use Teflon tape or paste on the fittings.

1. If removed, install inlet and outlet fittings in the rear cover of the fuel pump.
2. Install drive coupling in drive hub of the fuel pump and affix a new gasket to the mounting flange of the pump.

NOTE:
When correctly positioned, the outlet fitting on the pump should be in approximately 8 o'clock position when viewed from the rear, and the drain opening in the pump body facing down.

3. Index the drive coupling with the drive hub on the end of the air compressor crankshaft and align the pump mounting bolt holes with those in the air compressor rear cover.
4. Seat the fuel pump squarely against the air compressor piloting the flange on the pump body in the opening in the rear cover of the compressor. Install three (3) fuel pump mounting bolts and tighten them to 30–38 N·m (22–28 lb·ft).
5. Connect the fuel inlet and outlet lines to the fuel pump and tighten.
6. Prime engine fuel system before starting engine to ensure pump seal lubrication and prompt engine starting.

2.5 FUEL PUMP DRIVE

The fuel pump drive assembly consists of an aluminum housing, a helical gear driven off the bull gear, a drive shaft supported in the middle by a double–row ball bearing, and a forked hub which mates with a drive coupling. The fuel pump drive is supplied as an assembly, so components are not serviced. The drive gear and hub are pressed onto the drive shaft. A rubber O–ring located in a groove machined into the mounting surface of the drive is used to seal the fuel pump assembly to the gear case. An internal–type snap ring is fitted to a groove in the fuel pump drive housing to retain the bearing and shaft.

The coupling between the fuel pump and fuel pump drive hubs is plastic, and acts as a shock absorber in the fuel pump drive line.

2.5.1 Lubrication of Fuel Pump Drive Bearing

The fuel pump drive bearing is lubricated by engine oil splash–fed by the gears rotating in the gear case. This oil feeds the bearing and drive shaft through a hole in the fuel pump drive housing.

2.5.2 Removing Fuel Pump Drive Assembly

Remove the fuel pump drive assembly as follows:

1. Remove the bolts retaining the assembly to the gear case.

NOTICE:
Failure to remove the fuel pump drive assembly by pulling it straight out may damage the O–ring.

2. Remove the fuel pump drive assembly by pulling it straight out of the gear case.

2.6 FUEL FILTERS (SPIN–ON)

Two spin–on type filters are used on the Series 50 engine. The first in the fuel flow is a strainer, and the second is a filter. Although they are not marked as such, the threaded sleeves that accept the cartridges are different sizes to prevent mismatching. The primary filter has a 1 in. x 12 thread. The secondary filter has a 13/16 in. x 12 thread. The word "Primary" or "Secondary" is cast into the top of the respective adaptor. See Figure 2–41.

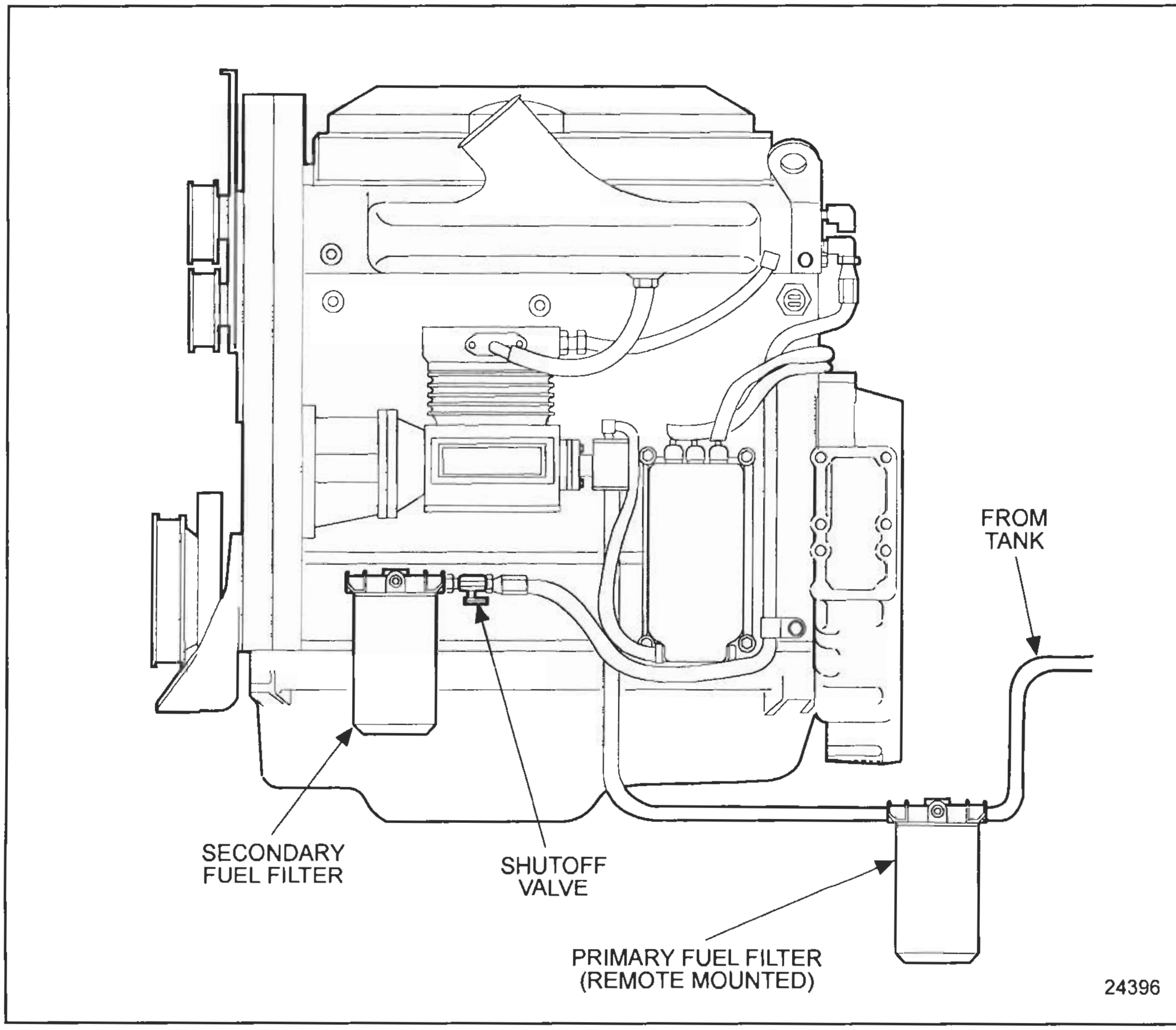


Figure 2–41 Fuel Filters

The spin–on filter cartridges consist of a shell, element, and gasket combined into a unitized replacement assembly. No separate springs or seats are required to support the filters. Effective with 1993 engine production, an optional fuel filter/water separator assembly may be installed in place of the strainer. A fuel shut–off valve or check valve may be installed on the outlet side of the secondary filter.

The fuel filter adaptors are retained to the block with two bolts each. Tighten these bolts to 58–73 N·m (43–54 lb·ft) torque.

The fuel filter system consists of the following:

- Spin–on primary fuel filter
- Primary fuel filter adaptor
- Spin–on secondary fuel filter
- Secondary fuel filter adaptor
- Fuel shut–off valve or check valve

2.6.1 Replacement of Filter

As contaminants build up on the filter medium, a number of factors start to affect vehicle performance:

- The fuel delivery rate is reduced, making less fuel available for combustion.
- The fuel pump is forced to work harder to move the same volume of fuel. This subjects internal seals to abnormal conditions which may lead to seal leakage. In extreme cases air can be drawn into the fuel system.
- With the rate of flow slowed, fuel stays in the cylinder head for a longer period of time, allowing its temperature to rise above normal. Because fuel temperature has an effect on engine power, higher fuel temperatures normally result in reduced power.
- If the restriction is severe enough, fuel vaporization can occur, resulting in pockets of air that can further reduce fuel delivery.

All of these conditions can lead to power loss and subsequent operator complaints of "low power" and "reduced vehicle fuel economy" caused by the need to downshift more frequently on grades.

To determine if replacement of fuel filter element is necessary. See Figure 2–42.

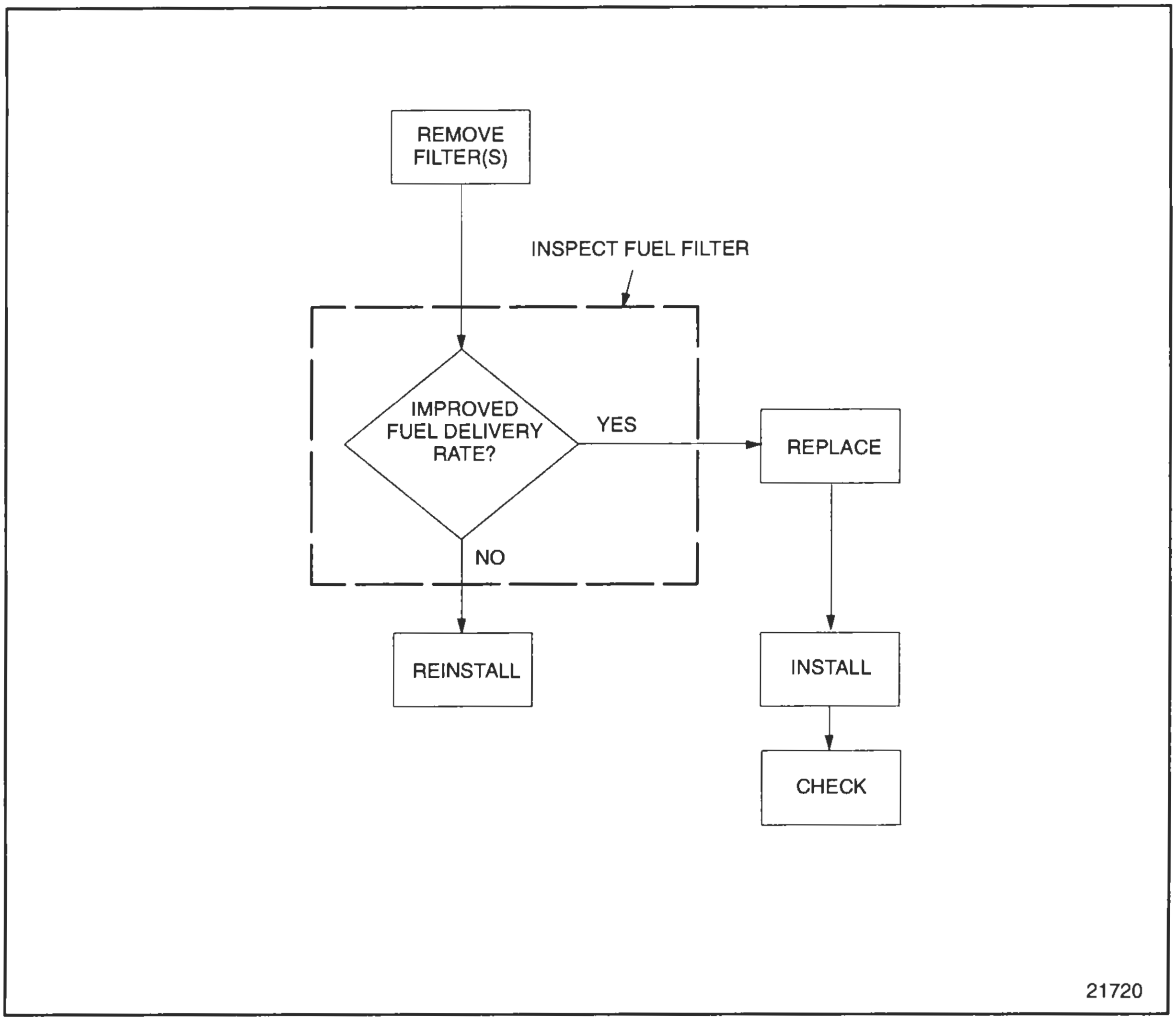


Figure 2–42 Flowchart for Replacement of Fuel Filter Element

To replace the filter, perform the following steps:

1. Use a suitable band wrench or filter wrench, such as J 22775, to remove the filter(s).
2. To install, fill the new filter replacement cartridges with clean fuel oil. Coat the gaskets slightly with clean fuel oil.

NOTICE:
Mechanical tightening of the fuel filters is not recommended, and may result in seal damage, cartridge damage, or both. Tighten the fuel filters by hand only.

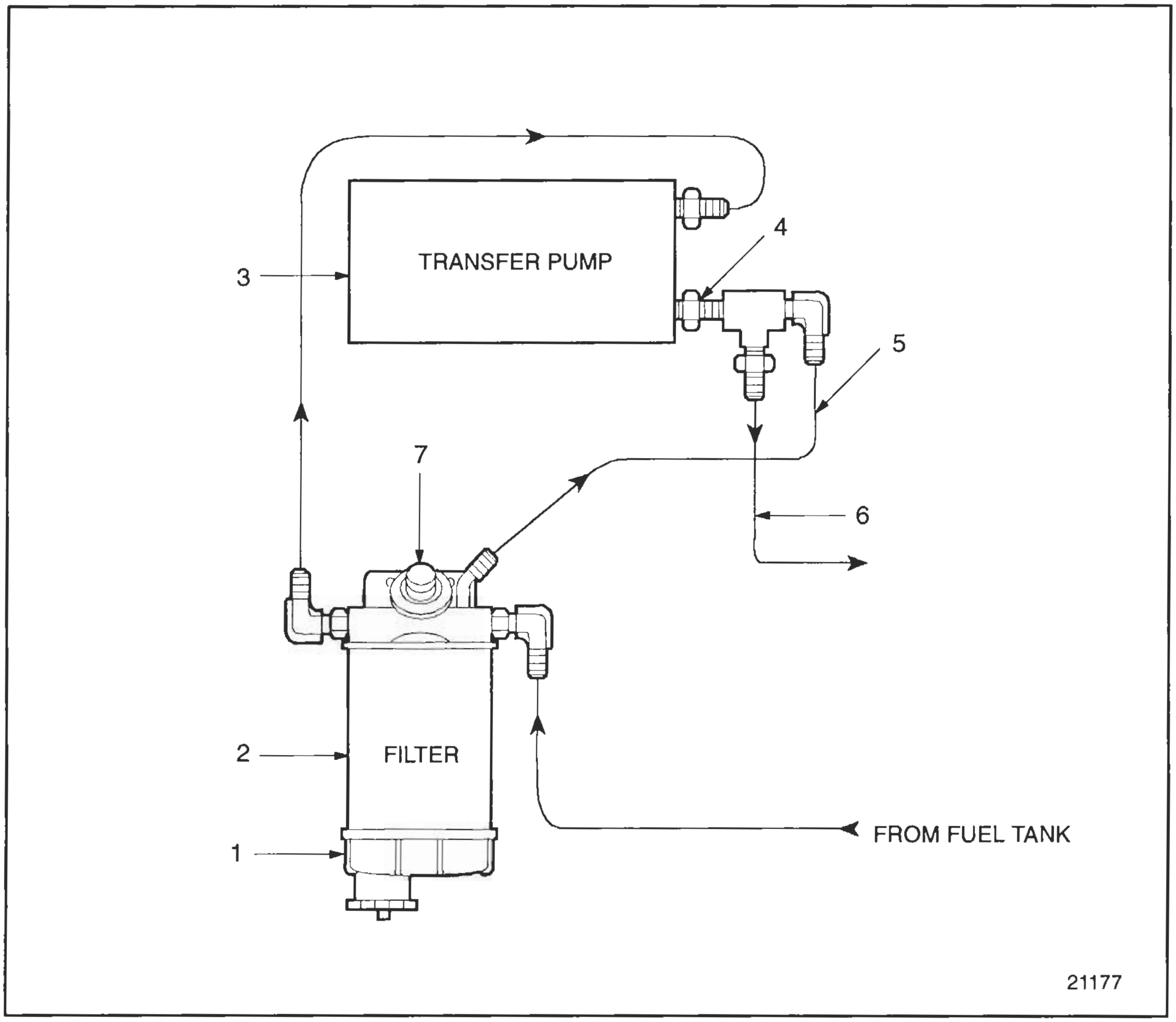
3. Thread the new filters on the adaptor, turning them until they contact the gasket fully with no side movement of the filter evident; then turn an additional one–half turn by hand.

NOTE:
There is a fuel system shutoff valve on the discharge side of the secondary fuel filter. This valve is designed to prevent loss of fuel prime at time of filter replacement.

4. Start the engine and check for leaks.

2.7 FUEL FILTER AND WATER SEPARATOR ASSEMBLY

The fuel filter and water separator assembly facilitates the settling of water in a collection bowl. See Figure 2–43.



1. Collection Bowl
2. Spin–on Element
3. Priming Pump
4. Reducer Bushing
5. Hose from Filter Head to Transfer Pump Discharge
6. Hose to Secondary Fuel Filter

Figure 2–43 Typical Fuel Filter/Water Separator Installation

2.7.1 Replacement of Fuel and Water Separator Element

Use the following procedure:

1. Drain off some fuel by opening the drain valve on the collection bowl. Close the valve.
2. Remove the element and bowl together, then remove the bowl from the element. Clean the bowl and the O-ring gland.
3. Apply a coating of clean fuel or grease to the new O-ring and element seal. Spin the bowl onto the new element and them spin the assembly onto the filter head by hand until snug. Do not use tools to tighten.
4. To eliminate air from the filter, operate the primer pump until the fuel purges at the filter assembly.
5. Start the engine and check for fuel leaks. Correct any leaks with the engine shut off.

2.7.2 Fuel Return System Check Valve

The purpose of the check valve is to reduce the risk of fuel prime loss and fuel siphoning from the head when the fuel filter is removed.

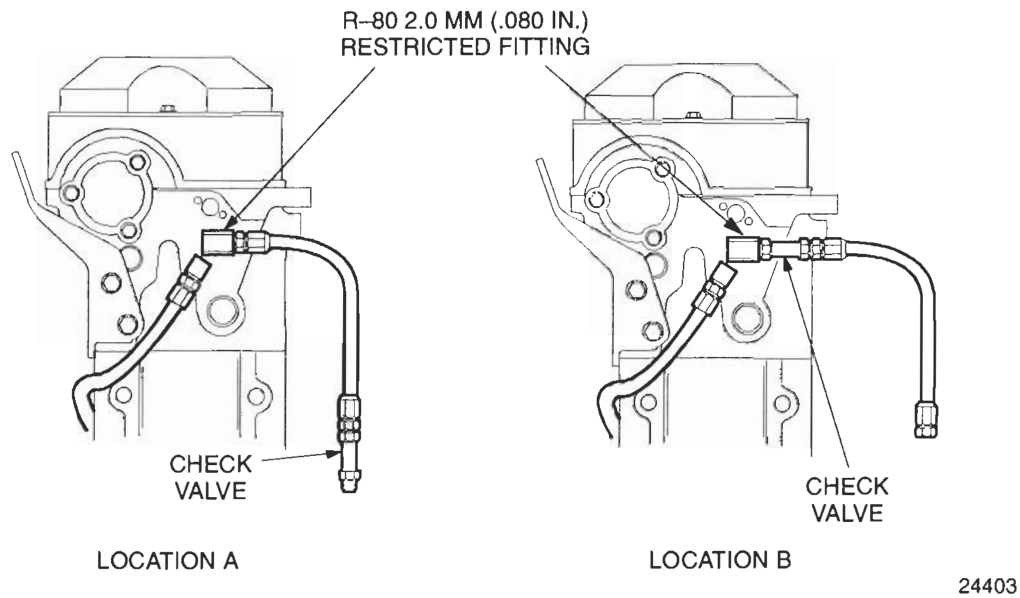


Figure 2–44 Typical Fuel Return Check Valve Locations

NOTICE:
The check valve must be included in the fuel system. If the check valve is removed for any reason or found to be defective, a new valve must be installed and the fuel system primed before start–up. The R–80 (.080 in., 2.0 mm) restricted fitting (elbow connector) which is ahead of the check valve must also be included in the fuel system.

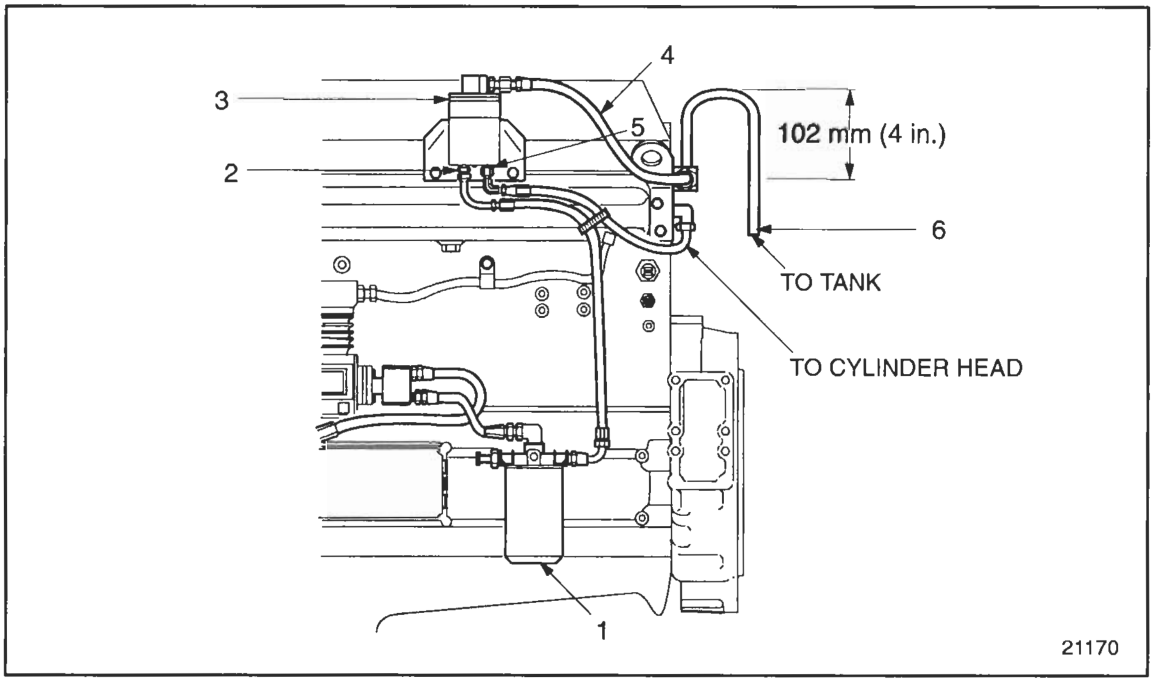
A check valve is connected to a hose in the fuel return line coming from the rear of the cylinder head or at the cylinder head restricted fitting, depending on individual installation requirements. See Figure 2–44.

2.7.3 PRO–CHEK® Fuel System Check Valve Installation

The PRO–CHEK® fuel system check valve is an optional item which, when properly installed removes air from the fuel supply line between the secondary filter and the cylinder head. No priming is required even after filter change, since any air that may get into the lines is automatically removed when it reaches the PRO–CHEK® valve.

Install the PRO–CHEK® valve as follows:

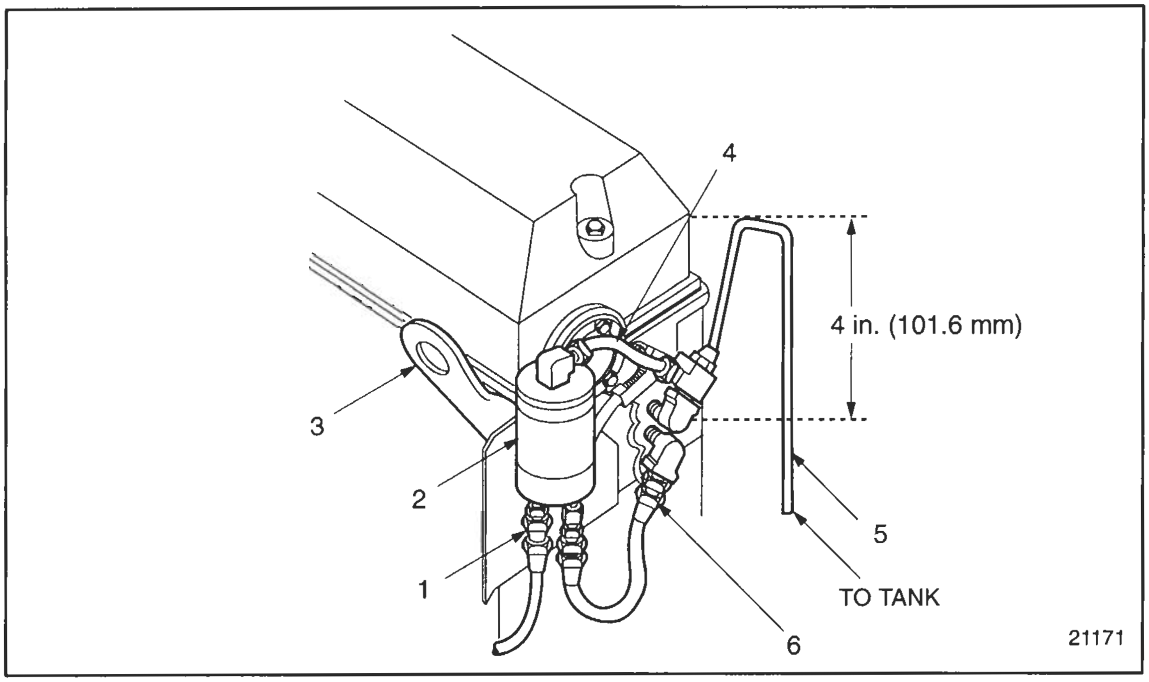
1. Mount the PRO–CHEK® valve on the side or rear of the Series 50 engine.
   [a] If side–mounted, install with two 10 mm bolts and spacers. The location may be ahead of or behind the location shown. See Figure 2–45.



1. Secondary Fuel Filter
2. Fuel Inlet
3. PRO–CHEK®
4. Air Purge Line
5. Fuel Outlet
6. Fuel Spill Line

Figure 2–45 Typical Side–mounted PRO–CHEK® Installation

[b] If rear–mounted remove the two 12 mm bolts holding the rear lifter bracket and install the PRO–CHEK® valve against the bracket with two 12 mm bolts that are 5 mm (approx. .20 in.) longer and two spacers. See Figure 2–46.



1. Fuel Inlet
2. PRO–CHEK®
3. Engine Lifter Bracket
4. Air Purge Line
5. Fuel Spill Line
6. Fuel Outlet

Figure 2–46 Typical Rear–mounted PRO–CHEK® Installation

2. Disconnect the fuel supply hose assembly at the rear of the engine and reconnect it to the PRO–CHEK® 3/8 in. SAE flared bottom fitting marked with the words *Fuel In.*
3. Connect a separate fuel hose assembly to the 1/4 in. 18 NPTF PRO–CHEK® female bottom fitting marked with the words *Fuel Out.* Install the other end in the fuel manifold inlet port at the rear of the engine.
4. An R80 2.0 mm (.080 in.) restricted fitting is installed in the fuel spill (return) opening in the cylinder head. Install a tee fitting after the R80 spill fitting. The spill hose from this tee fitting must be routed at least 4 in. (101.6 mm) above the fuel gallery. See Figure 2–45 and see Figure 2–46. Connect a 1/4 in. diameter fuel hose assembly to the elbow in the top port of the PRO–CHEK®. Route this air purge hose to the spill tee fitting.
5. Tie–wrap the PRO–CHEK® inlet and outlet fuel lines to prevent chafing and/or contact with metal parts.
6. Prime the fuel system.

7. Start the engine and check for leaks.

The PRO–CHEK® valve is fully assembled and ready to install when received. If the *Fuel In* or *Fuel Out* fittings are accidentally loosened or removed for any reason, they must be reinstalled in their proper locations as follows:

- ☐ The male fitting with the long, solid pipe is installed in the fuel in port. See Figure 2–47.
- ☐ The female fitting with the short, perforated pipe is installed in the fuel out port. See Figure 2–47.

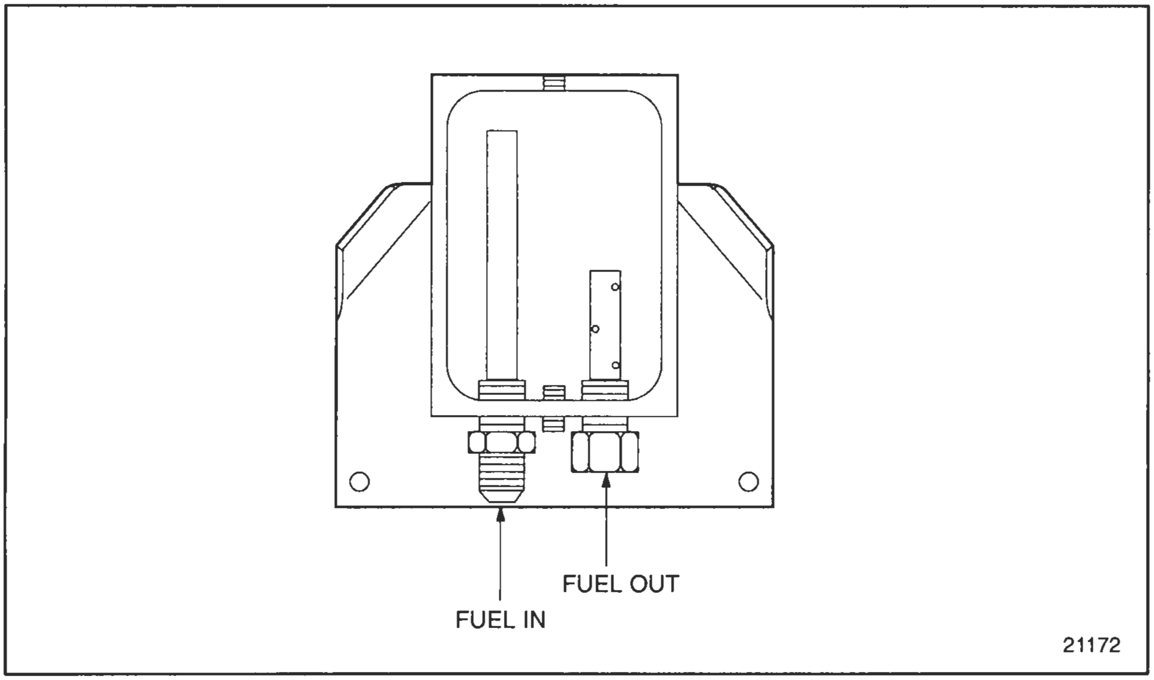


Figure 2–47 PRO–CHEK® Cutaway View

2.8 ELECTRONIC ENGINE CONTROL

The Detroit Diesel Electronic Control System (DDEC) controls the timing and amount of fuel injection by the electronic unit injectors (EUI). The system also monitors several engine functions using electrical sensors which send electrical signals to the Electronic Control Module (ECM). The ECM then computes the incoming data and determines the correct fuel output and timing for optimum power, fuel economy and emissions. The ECM also has the ability to display warnings or shut down the engine completely (depending on option selection) in the case of damaging engine conditions, such as low oil pressure, low coolant, or high oil temperature.

The current engines have the third generation DDEC system, DDEC III. See Figure 2–50. Former Series 50 engines had DDEC II systems.

The replacement of DDEC components is based on indicated diagnostic codes leading to faulty components. Check the *DDEC Troubleshooting Manual, 6SE489, DDEC II,* 6SE492, or *Series 50 Troubleshooting Manual*, 6SE494, for more complete information on diagnosis of components and system problems.

2.9 DDEC III

DDEC III provides an indication of engine and vehicle malfunctions. The ECM continually monitors the DDEC III system. See Figure 2-48.

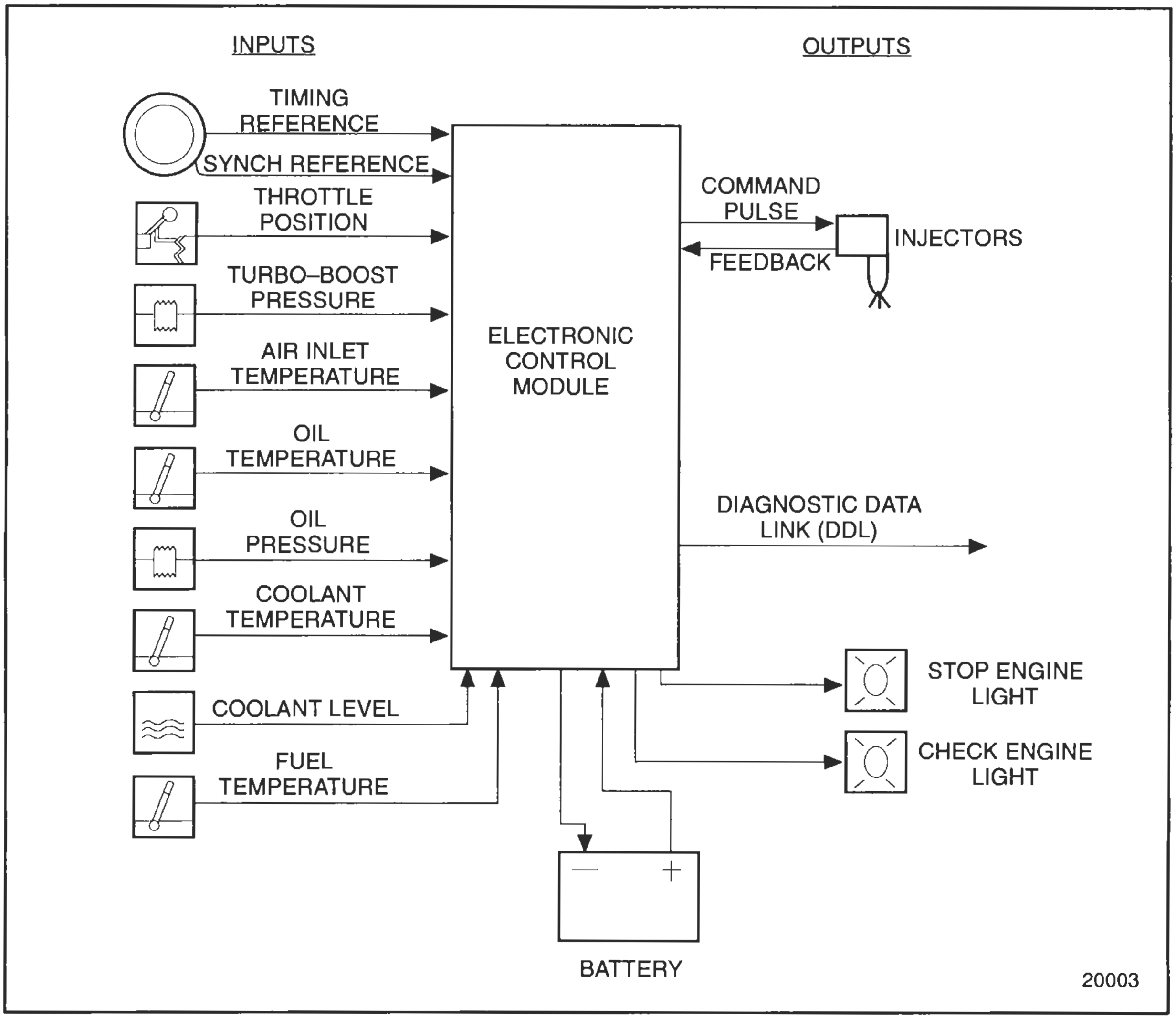


Figure 2-48 DDEC III System

Any faults that occur are stored as codes in the ECM's memory. These codes can be accessed in any of three ways:

1. A DDR can be used to read the codes. See Figure 2-49.
2. A personal computer (PC) connected to the ECM through a translator device which converts J 1708 to RS232 protocol.

3. The Check Engine Light (CEL) or the Stop Engine Light (SEL) is illuminated.
   - If the CEL, a panel mounted yellow indicator light, is illuminated this indicates the condition should be diagnosed as soon as convenient.
   - If the SEL, a panel mounted red indicator light, and CEL are illuminated a major fault has occurred and immediate attention is required to avoid potential engine damage. Automatic engine shutdown or rampdown is available as an option. A shutdown override switch is required to allow the vehicle to be moved to a safe location during automatic shutdown or rampdown.

DDEC III features programmable with a Diagnostic Data Reader (DDR) are:

- Password
- Droop
- Active hp braking
- Cruise control
- Engine brake
- Cruise control
- Vehicle speed limiting
- Vehicle speed sensor
- Variable Speed Governor cruise switch
- Idle timer shutdown
- Idle timer between air temperatures
- Vehicle ID number (VIN)
- Idle adjustment
- Progressive shifting
- Engine protection

The hand-held DDR is used on engines equipped with DDEC III to display engine description, diagnostic data, fault codes, and to program the ECM calibration. A printout of the information displayed on the DDR, can be obtained by attaching a printer. The diagnostic data reader kit, J 38500-D, includes a reader, cable, carrying case, DDEC cartridge, manual, and a 6-pin adaptor. See Figure 2-49.

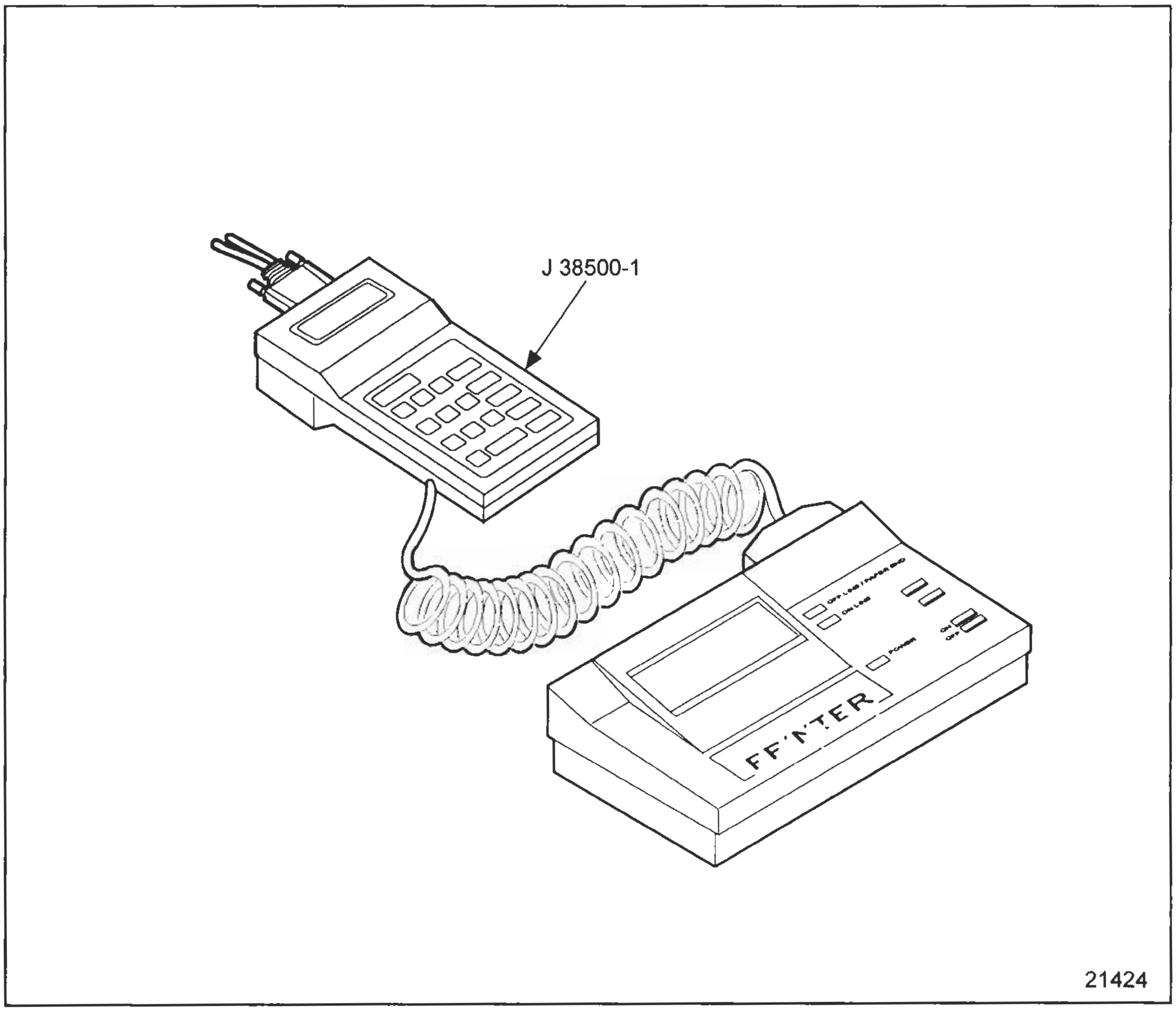


Figure 2-49 The DDR and Printer

The SAE Standard Communications of the DDEC III system are listed in Table 2–2. The fan control inputs and outputs for DDEC III are listed in Table 2–3. The engine brake control features of DDEC III are listed in Table 2–4. DDEC III can identify faulty components and other engine–related problems by providing the technician with a diagnostic code. A comparison of DDEC II and DDEC III engine hardware is listed in Table 2–5. A comparison of DDEC II and DDEC III standard sensors is listed in Table 2–6 and a comparison of optional sensors is listed in Table 2–7.

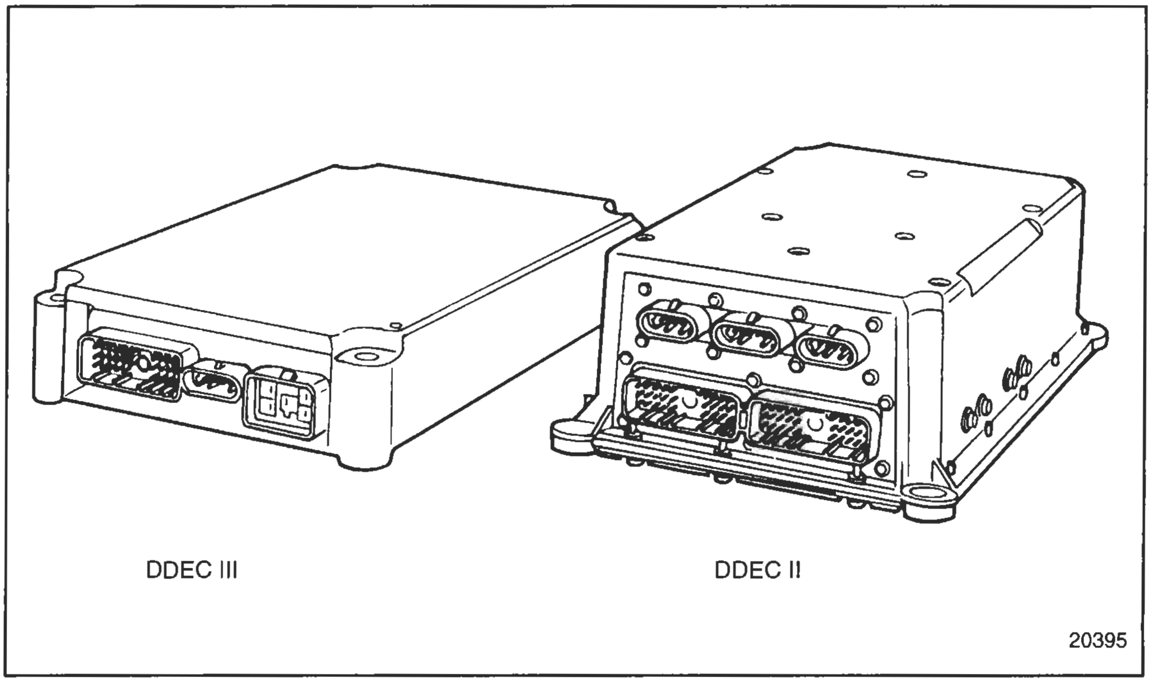


Figure 2–50 DDEC III and DDEC II Electronic Control Module (ECM)

SAE Standard Communication
SAE J1587 protocol on J1708 hardware
Diagnostics
Electronic dashes
Data Hub
SAE J1922 protocol on J1708 hardware
Traction control systems
Transmission controls
SAE J1939 high speed data link
Vehicle controls

Table 2–2 SAE Standard Communications for DDEC III

Inputs	Outputs
Coolant temperature	Single on/off fan clutch
Oil temperature	Dual on/off fan clutch
Air Temperatures	2–speed single fan
Air conditioning	Modulated fan clutch

Table 2–3 Fan Controls for DDEC III

Engine Brake Control
Eliminates OEM engine brake module
Compatible with cruise control
Engine brake will go and off without disabling cruise control
Engine fan braking
Requires fan and engine brake control
Fan turn on when engine brake is on high
In cruise control, engine brake operates electronically
MPH activating speeds are set with DDR
Cruise control, engine brake operates manually

Table 2–4 Engine Brake Control with DDEC III

Engine Hardware	DDEC II	DDEC III
Electronic Foot Pedal Assembly	3 Wires	3/4 Wires
Coolant Level Sensor	Coolant Probe/Module	Coolant Probe Only
Diagnostic Request Stop Engine Override	2 Separate Switches	1 Combined Switch
Communications	Vehicle Interface Harness SAE J1587/J1922	Vehicle Interface Harness SAE J1587 Communications Harness SAE J1922, SAE J1939
Power Harness	6 Pin Connector	5 Pin Square Connector
Wiring	16 gage wire, 4 Power, 2 Ground	12 gage wire (Eliminates Splicing), 2 Power, 2 Ground

Table 2–5 DDEC II vs DDEC III

DDEC II	DDEC III
Oil Temperature (Truck)	Oil Temperature
Oil Pressure	Oil Pressure
Coolant Level	Coolant Level
Turbo Boost	Turbo Boost
Throttle Position (OEM Supplied)	Throttle Position
Timing Reference	Timing Reference
Synchronous Reference	Synchronous Reference
Fuel Temperature	Fuel Temperature, Air Temperature

Table 2–6 Standard Sensors

DDEC II	DDEC III
Fuel Pressure	Fuel Pressure
Pressure Governor (Firetruck)	Pressure Governor (Firetruck)

Table 2–7 Optional Sensors

2.9.1 Repair or Replacement of the DDEC III ECM

The DDEC III ECM is a sealed, nonserviceable unit. Tag defective ECM for recore.

2.9.2 Removal of the DDEC III ECM

Perform the following steps for ECM removal:

1. Carefully disengage the lock tab on the power harness and injector harness connectors when removing.
2. Remove the two (2) wire and three (3) wire harness connections at the ECM.
3. Remove the thru–bolts holding the ECM to the engine.
4. Remove the ECM and cold plate from the engine, if so equipped.
5. Remove the screws securing the cold plate to the ECM. Remove the cold plate from the ECM, if so equipped.

2.9.3 Installation of the DDEC III ECM

Perform the following steps for ECM installation:

1. Install the cold plate on the ECM, if so equipped. Tighten the screws securing the cold plate to the ECM. Use Loctite 262, or equivalent, on the cold plate–to–ECM screws. Tighten to 9.5–12 N·m (84–106 lb·in.) torque.
2. Inspect the ECM isolators for damage and replace if required.
3. Mount the ECM and cold plate to the engine.
4. Secure the ECM to the engine with thru–bolts. Tighten the ECM–to–engine bolts to 23–27 N·m (17–20 lb·ft). Tighten the ECM connector hold–down screws to 2.4–3.0 N·m (21–26 lb·in.) torque.
5. Connect the two (2) wire and three (3) wire harness connections at the ECM.
6. Engage the lock tab on the power harness and injector harness connectors.
7. Turn the ignition to the "ON" position. Observe or read any diagnostic codes. If any code except code 25 is obtained, refer to the *Troubleshooting Manual*, 6SE494.
8. Start the engine, and check for fuel leaks.

2.10 DDEC II ECM

This system utilizes an engine mounted ECM with a replaceable PROM in the DDEC II ECM and an EEPROM in the DDEC II ECM. The ECM has isolator mounts for both vibration and electrical isolation. Depending upon application, some units have fuel cooling of the ECM. The engine mounted system simplifies vehicle wiring for greater reliability.

The DDEC II ECM is a microprocessor. It is the control center of the DDEC II system. See Figure 2–51.

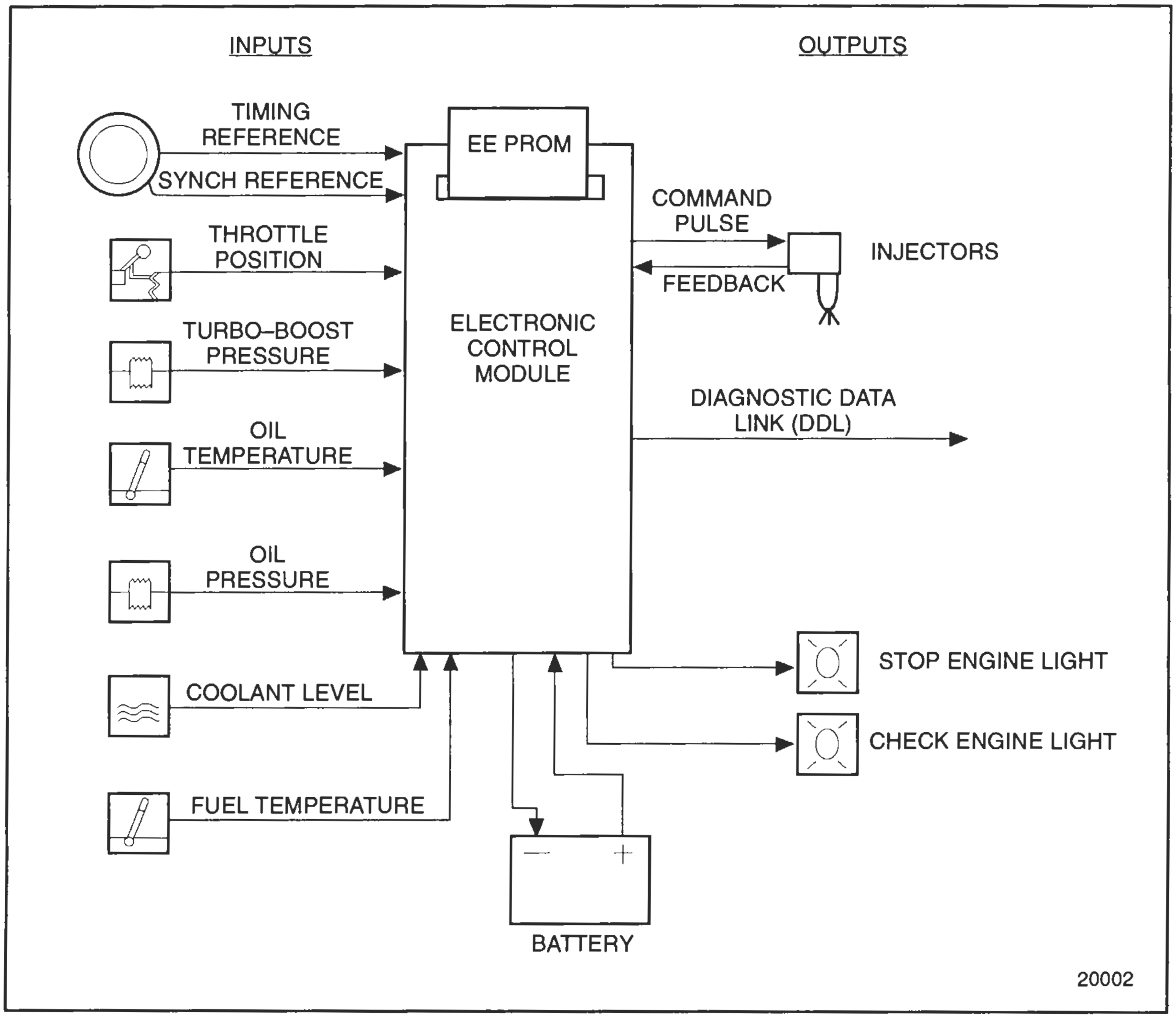


Figure 2–51 Schematic Diagram of DDEC II

The DDEC II ECM is packaged in a die–cast aluminum housing with sealed connectors, see Figure 2–51. It is mounted on the left side of the engine block.

The DDEC II consists of the following:

- ❑ The DDEC II ECM
- ❑ A replaceable EEPROM
- ❑ Connections to various engine sensors, operational displays, power and fuel injectors

2.10.1 Repair or Replacement of the DDEC II ECM

The DDEC II ECM is a sealed, nonserviceable unit. Tag defective ECM for recore.

2.10.2 Diagnostic Procedures

Before attempting any diagnosis of the system, read section 2, "Basic Knowledge Required," and section 3, "Testing the DDEC System," of the *DDEC Troubleshooting Guide,* 6SE489. Basic mechanical checks should be made beforehand to verify that the problem is definitely related to the electrical portion of the system. If the basic mechanical checks fail to locate the problem, start the electrical diagnosis with the Troubleshooting Charts as described in the *DDEC Troubleshooting Manual,* 6SE494.

There are two diagnostic data readers that can be used on DDEC II ECMs. See Figure 2–52, and see Figure 2–53.

2.10.3 Removal of DDEC II ECM

Perform the following steps for ECM removal:

1. Carefully disengage the lock tab on the power harness and injector harness connectors when removing.
2. Remove the five (5) wire harness connections at the ECM.
3. Remove the thru-bolts holding the ECM to the engine.
4. Remove the ECM and cold plate from the engine.

2.10.4 Installation of DDEC II ECM

Perform the following steps for ECM installation:

1. Inspect the ECM isolators for damage and replace if required.
2. Mount the ECM and on the engine.
3. Secure the ECM to the engine with thru–bolts. Tighten the ECM–to–engine bolts to 23–27 N·m (17–20 lb·ft). Tighten the ECM connector hold–down screws to 2.4–3.0 N·m (21–26 lb·in.) torque.
4. Connect the five (5) wire harness connections at the ECM.
5. Engage the lock tab on the power harness and injector harness connectors.
6. Turn the ignition to the "ON" position. Observe or read any diagnostic codes. If any code except code 25 is obtained, refer to the *DDEC II Troubleshooting Guide*, 6SE489 or *Series 50 Troubleshooting Manual*, 6SE494.
7. Start the engine, and check for fuel leaks.

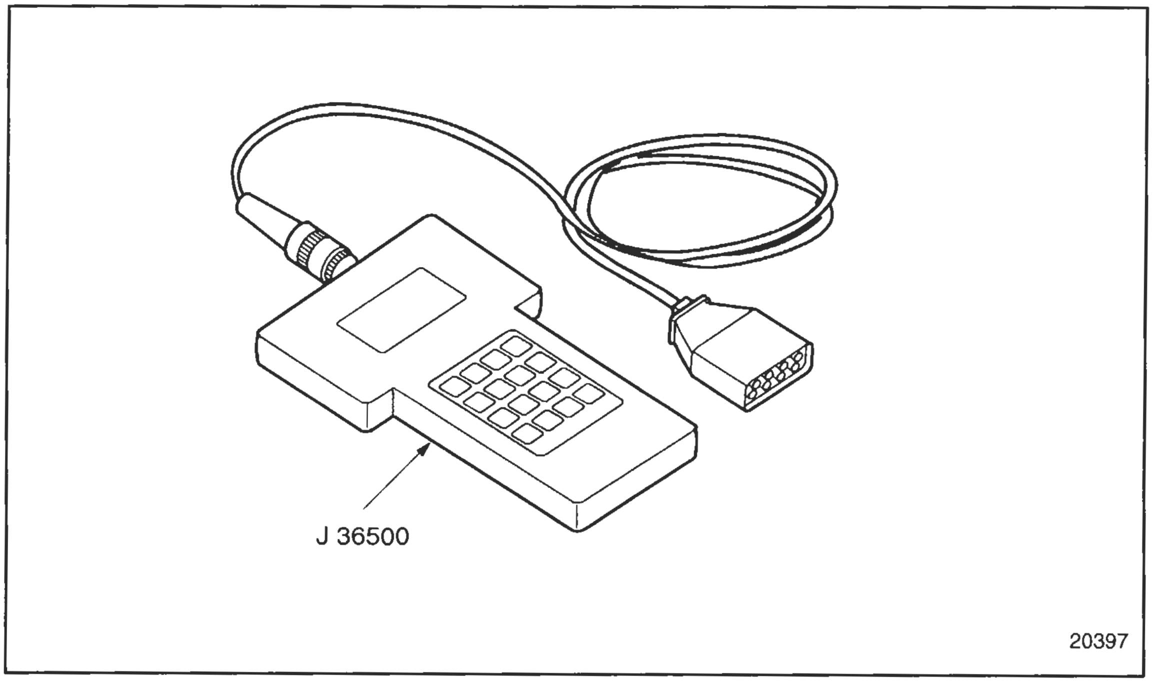


Figure 2–52 DDEC II Diagnostic Reader

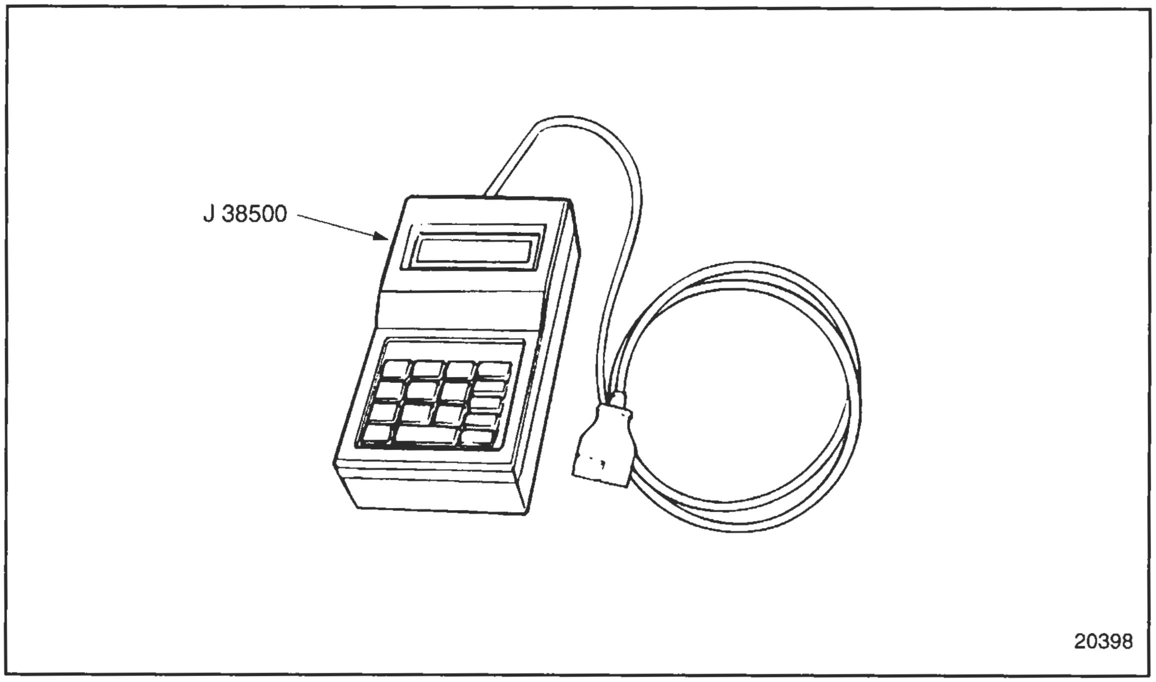


Figure 2–53 DDEC II Diagnostic Reader

If the diagnostic reader is not available, the following procedure can be used to read the fault codes using the "Check Engine" light on the dashboard of the vehicle. See Figure 2–54.

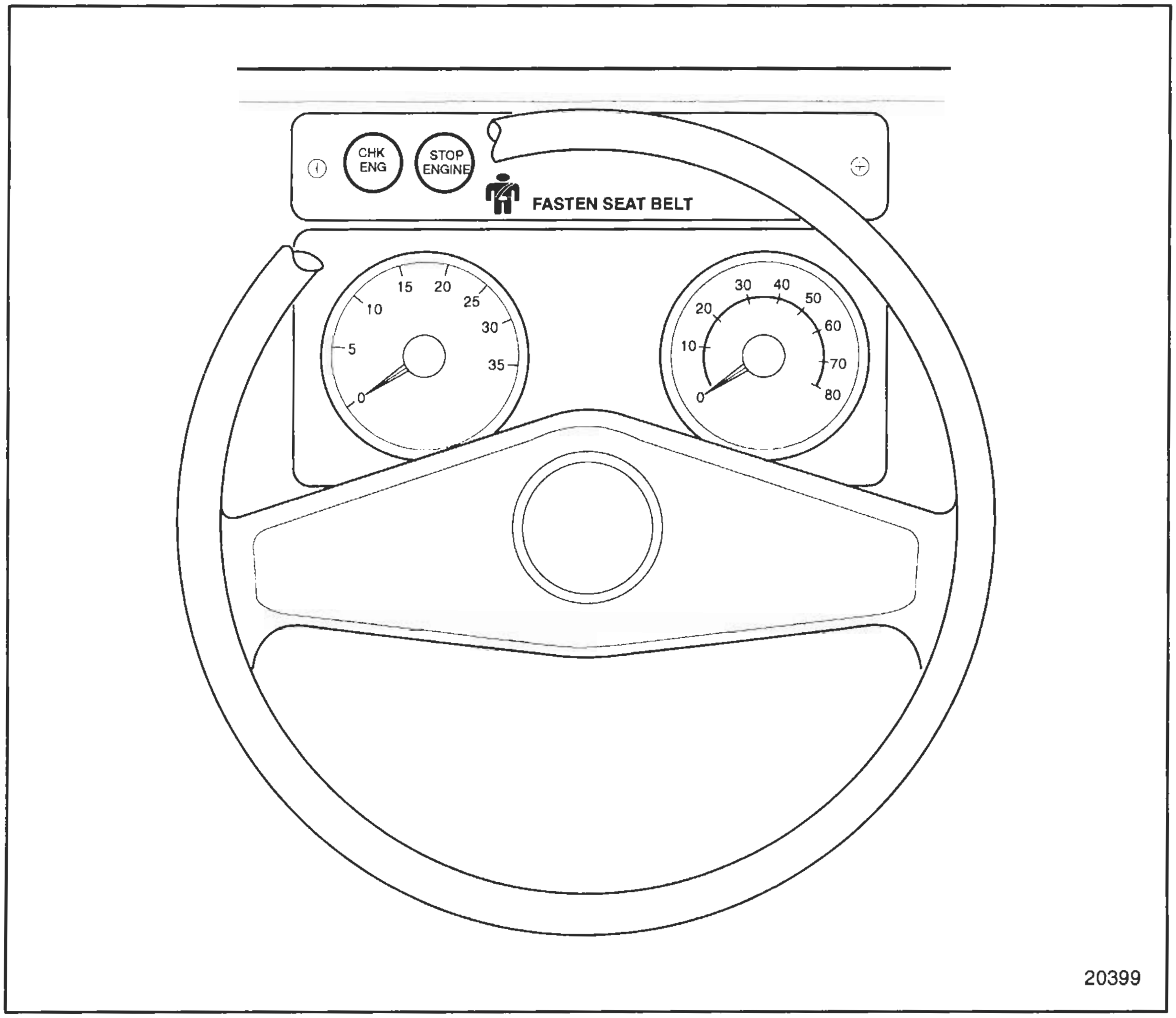


Figure 2–54 Dashboard Warning Lights

If the vehicle is equipped with an OEM supplied diagnostic switch, hold the switch in the "ON" position. This should be done with the ignition on and the engine not running.

If there is no diagnostic switch, locate the 12-pin Diagnostic Data Link (DDL) connector (DDEC II applications only) under the dash of the vehicle. See Figure 2-55. Using the jumper wire from the Kent-Moore diagnostic jumper wire kit, J 35751, or equivalent, connect pin A to pin M.

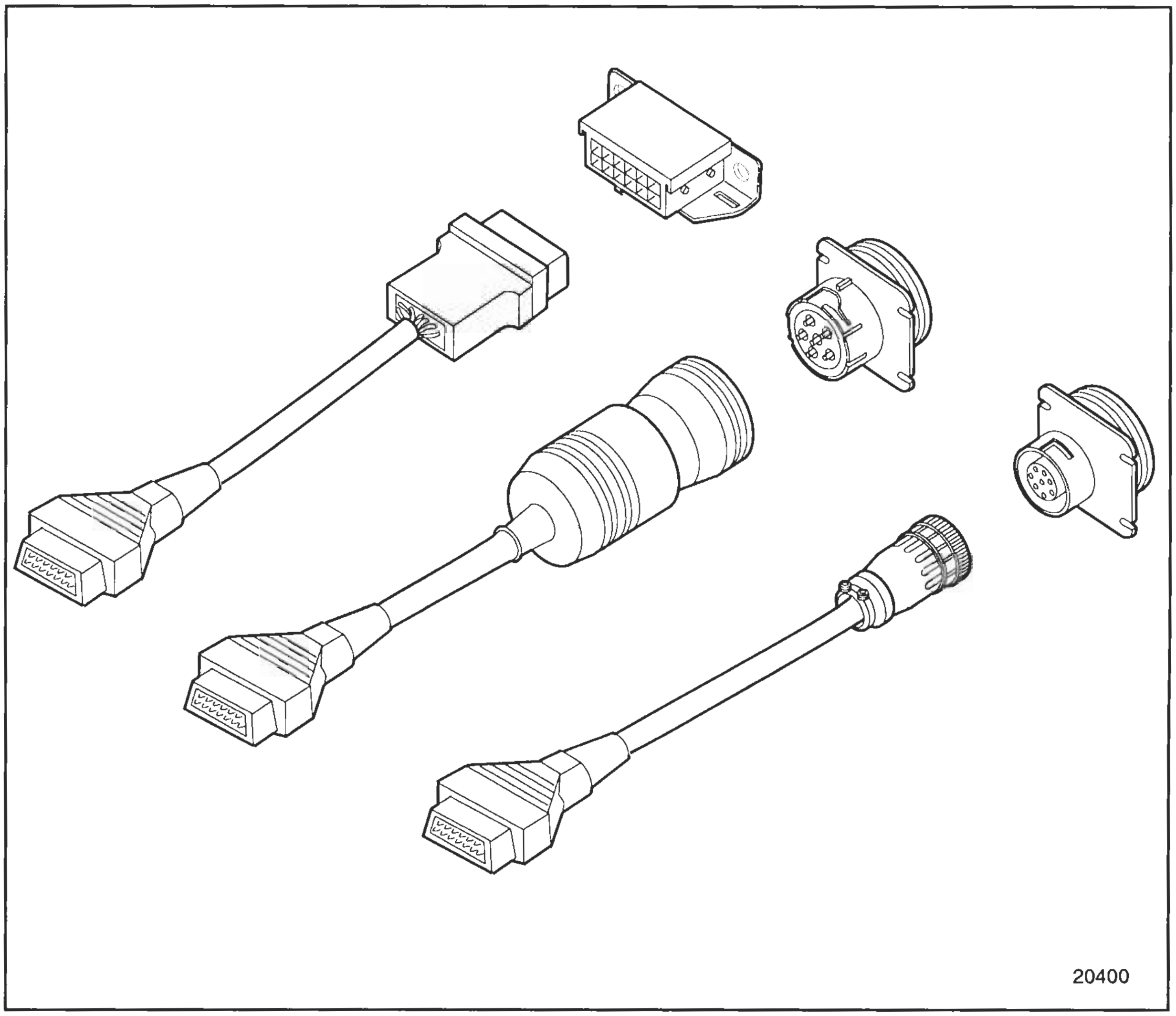


Figure 2–55 Examples of Diagnostic Data Link (DDL) Connector

NOTICE:
If the vehicle is equipped with an OEM supplied diagnostic switch, the switch must NOT be switched on when operating the vehicle. If this is done, the diagnostic mode line will be grounded, and the throttle will be forced to the idle position, affecting vehicle operation. The throttle will also go to idle if pins A and M in the DDL connector are jumped together. See Figure 2–56. This condition will not occur when a diagnostic reader is used.

These methods will cause the "Check Engine" light to begin flashing a code when the ignition is turned to the "ON" position. Code 25, for example, would be two flashes followed by a pause, followed by five more flashes. This code would indicate no trouble codes logged since the last system check. This flashing code will be repeated until the diagnostic switch is turned "OFF" or the jumper wire is removed from pins A and M (on DDEC II engines only).

If a code other than 25 is read, refer to the correct chart as instructed by the *DDEC Troubleshooting Manual,* 6SE494 for repair instructions.

Fault codes can be cleared from the DDEC II and III systems only by using a diagnostic reader. Follow the instructions supplied with the reader to clear the fault codes.

NOTE:
Before beginning any repair procedures, the ignition switch must be in the "OFF" position.

Following are basic replacement procedures for the DDEC components. Components should NOT be replaced unless a defective unit has been concluded by the *DDEC Troubleshooting Guide,*6SE489 (DDEC II) or *Series 50 Troubleshooting Manual,* 6SE494.

2.11 ELECTRONIC FOOT PEDAL ASSEMBLY

The Electronic Foot Pedal Assembly (EFPA) connects the accelerator pedal to a Throttle Position Sensor (TPS). See Figure 2-56. The TPS is a device that sends an electrical signal to the ECM. The signal varies in voltage according to the amount the pedal is pressed. The system is installed in the space normally occupied by the mechanical foot pedal. The EFPA has maximum and minimum stops that are built into the unit during manufacture.

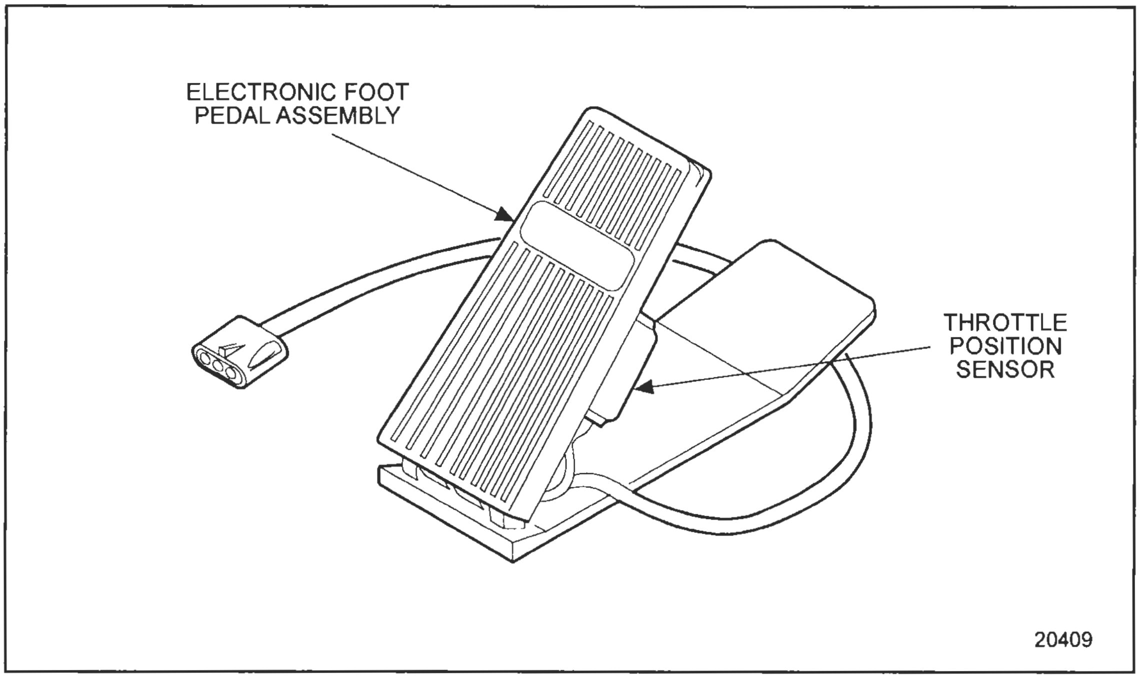


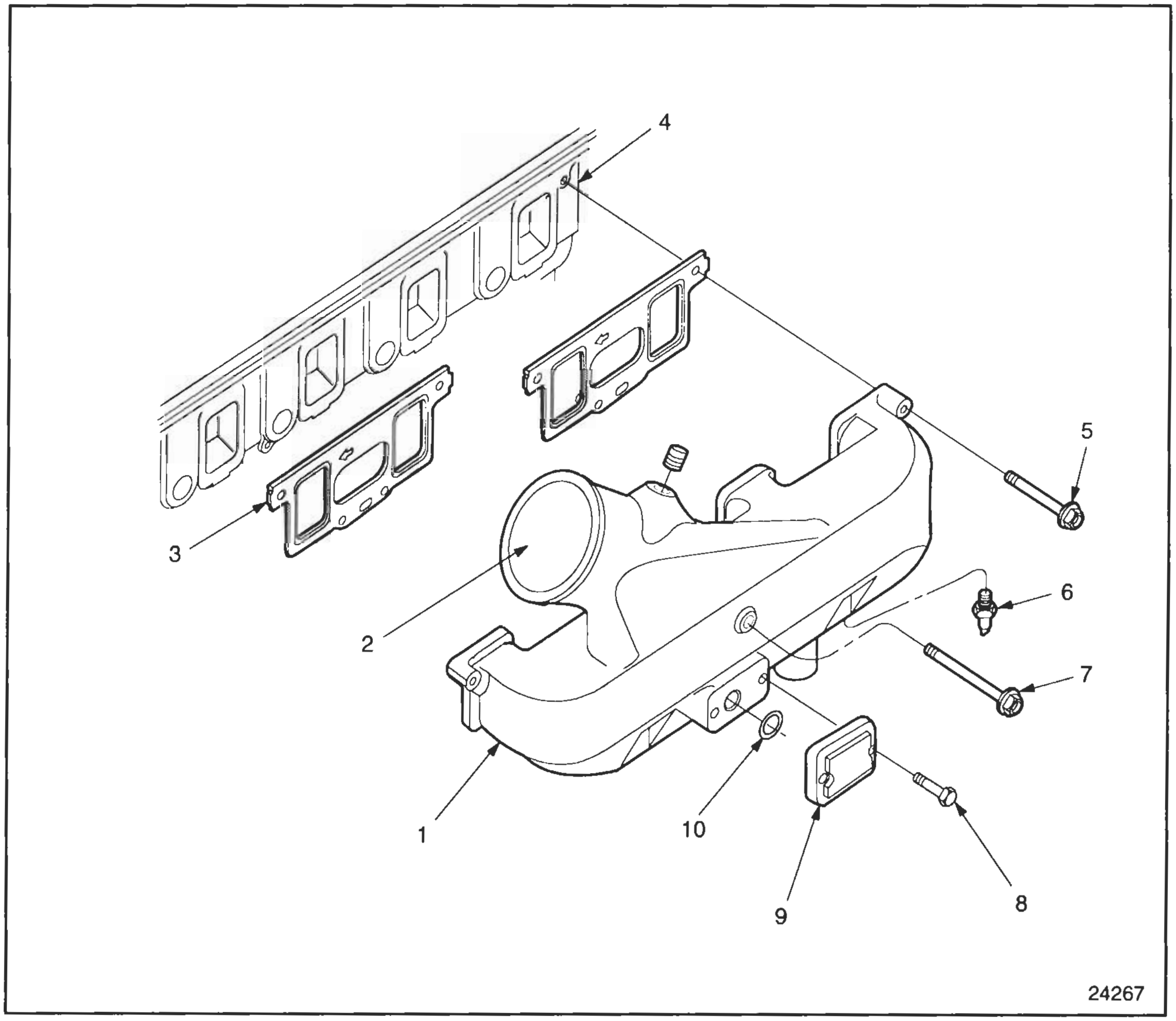
Figure 2–56 Electronic Foot Pedal Assembly

2.11.1 Repair or Replacement of EFPA

The EFPA assembly is supplied by the vehicle manufacturer. Refer to the Original Equipment Manufacturer for service procedure.

2.12 TURBO BOOST PRESSURE SENSOR

The Turbo Boost Sensor (TBS) is mounted to the intake manifold with two bolts. A rubber O–ring is used to seal the sensor to the manifold. See Figure 2–57.



1. Intake Manifold
2. Intake Manifold Inlet
3. Intake Manifold Gasket
4. Cylinder Head
5. Bolt
6. Air Temperature Sensor
7. Bolt
8. Turbo Boost Sensor Bolt
9. Turbo Boost Sensor
10. O–ring

Figure 2–57 Turbo Boost Pressure Sensor

This device is a pressure sensor that sends an electrical signal to the ECM. The ECM uses this information to compute the amount of air entering the engine. Fuel supply is regulated by the TBS information to control engine smoke.

2.12.1 Repair or Replacement of TBS

The TBS is non–serviceable and must be replaced as an assembly. No adjustment is required.

2.12.2 Removal of TBS

Remove the TBS as follows:

1. Disengage the locking tang on the TBS connector body. Grasp the terminal body and gently pull it from the sensor.
2. Remove the two bolts that secure the TBS to the intake manifold.

NOTE:
Be careful not to lose the O–ring.

3. Remove the TBS from the intake manifold.

2.12.3 Installation of TBS

Install the TBS as follows:

1. The TBS is an electronic device. Use care during installation.
2. Install the TBS to the intake manifold.
3. Install the two bolts that secure the TBS to the intake manifold.

NOTICE:
Do not overtighten the bolts that mount the TBS to the intake manifold. Damage to the TBS may result. Torque the bolts to no more than 2.4–3.0 N·m (21–26 in.·lb) torque.

4. Engage the locking tang on the TBS connector body. Grasp the terminal body and gently pull it towards the sensor
5. Put petroleum jelly on O–ring to hold it in position.
6. Turn the ignition to the "ON" position. Observe or read any diagnostic codes. If any codes other than 25 appears, refer to the *DDEC Troubleshooting Guide*, 6SE489 II or *Series 50 Troubleshooting Manual*, 6SE494.

2.13 OIL PRESSURE SENSOR

The Oil Pressure Sensor (OPS) is installed into the main engine oil gallery. A typical location is the left rear corner of the cylinder block. See Figure 2–58.

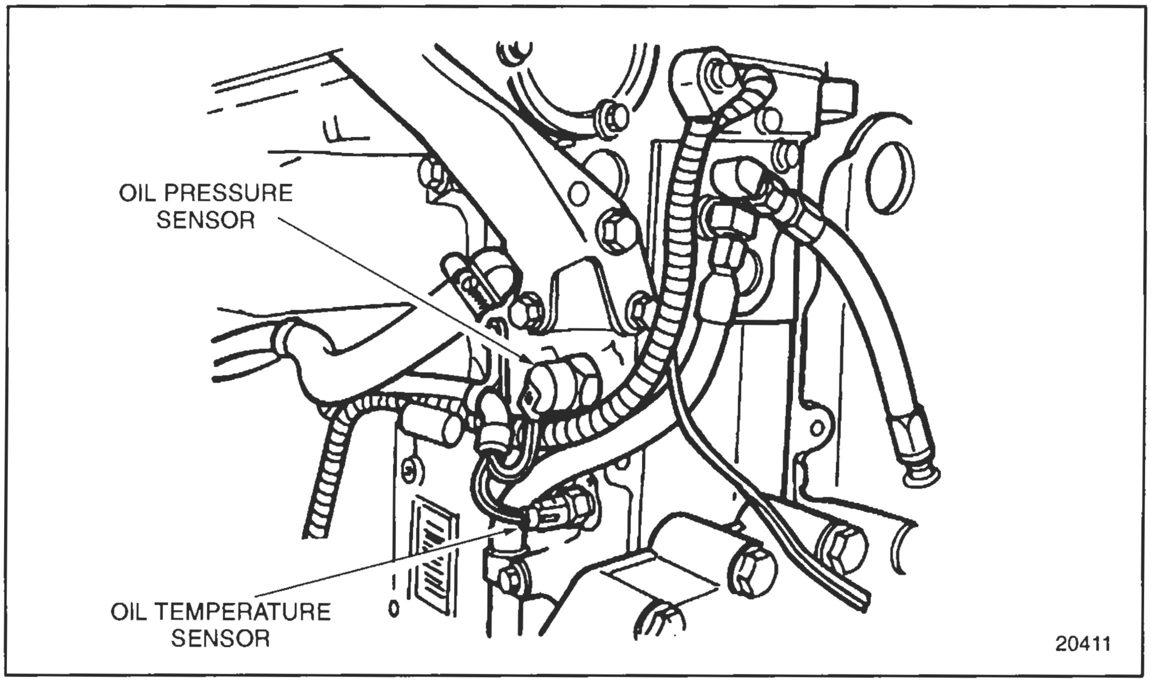


Figure 2–58 Engine Oil Pressure and Temperature Sensors

The OPS sends an electrical signal to the ECM telling it what the engine oil pressure is at any given speed. A low oil pressure signal exceeding seven seconds is used by the ECM to begin the stop engine or warning function.

2.13.1 Repair or Replacement of the OPS

The OPS is non–serviceable and should be replaced as a unit. No adjustment is required.

2.13.2 Removal of OPS

Remove the OPS as follows:

1. Disengage the locking tang on the three–wire connector. Grasp the body of the connector and gently pull it free of the OPS.
2. Use the appropriate wrench on the hex end of the OPS to unscrew it from the engine.

2.13.3 Installation of OPS

The OPS is an electronic device. Use care on installation.

Install the OPS as follows:

1. Place the sensor on the engine and using the appropriate wrench on the hex portion of the sensor tighten the screws.
2. Use Loctite Pipe Sealer with Teflon, J 26558–92, (or equivalent) on all but the first two threads of the OPS to prevent leaks.
3. Place the connector in the socket and engage the locking tang.
4. Turn the ignition to the "ON" position. Observe or read any diagnostic codes. If any code other than 25 is obtained, refer to the *DDEC Troubleshooting Guide,* 6SE489 II or *Series 50 troubleshooting Manual,* 6SE494.

2.14 OIL TEMPERATURE SENSOR

The Oil Temperature Sensor (OTS) is installed into the main engine oil gallery. A typical location is the left rear corner of the cylinder block. See Figure 2-59. The OTS sends an electrical signal to the ECM indicating engine oil temperature. The ECM uses this information to modify engine speed for better cold weather starts and faster warm-ups. Oil temperatures exceeding specification for two seconds or more will begin the stop engine or warning function.

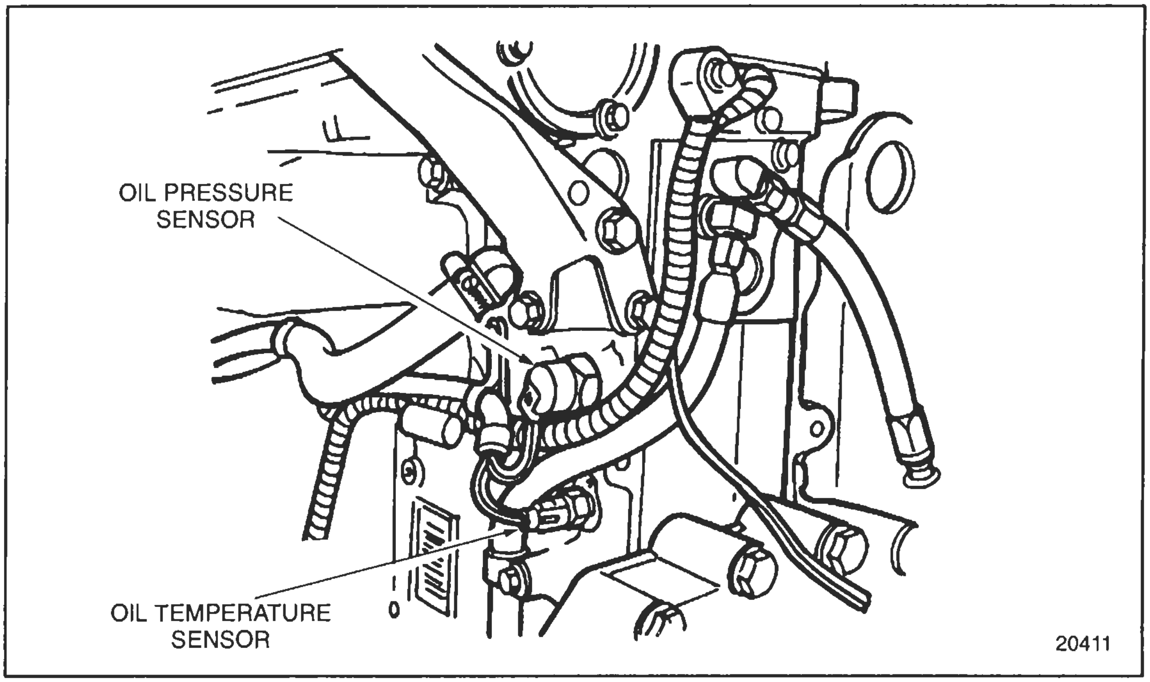


Figure 2–59 Engine Oil Pressure and Temperature Sensors

2.14.1 Repair or Replacement of OTS

The OTS is non–serviceable, and is replaced as a unit. No adjustment is required.

2.14.2 Removal of OTS

Removal the OTS as follows:

1. Disengage the locking tang on the two–wire connector.
2. Grasp the body of the connector and gently pull it from the socket.
3. Use the appropriate wrench on the hex portion of the sensor and unscrew it.

2.14.3 Installation of OTS

The Oil Temperature Sensor is an electronic device. Use care in the installation process.

Install the OTS as follows:

1. Place the sensor and using the appropriate wrench on the hex portion of the sensor tighten the screws.
2. Use Loctite Pipe Sealer with Teflon, J 26558–92 (or equivalent) on all but the first two threads of the OTS to prevent leaks.
3. Place the connector in the socket and engage the locking tang.
4. Turn the ignition to the "ON" position. Observe or read any diagnostic codes. If any code other than 25 appears, refer to the *DDEC Troubleshooting Guide,* 6SE489 or *Series 50 Troubleshooting Manual,* 6SE494.

2.15 SYNCHRONOUS REFERENCE SENSOR

The Synchronous Reference Sensor (SRS) is an electronic component that is mounted to the rear of the gear case. See Figure 2–60.

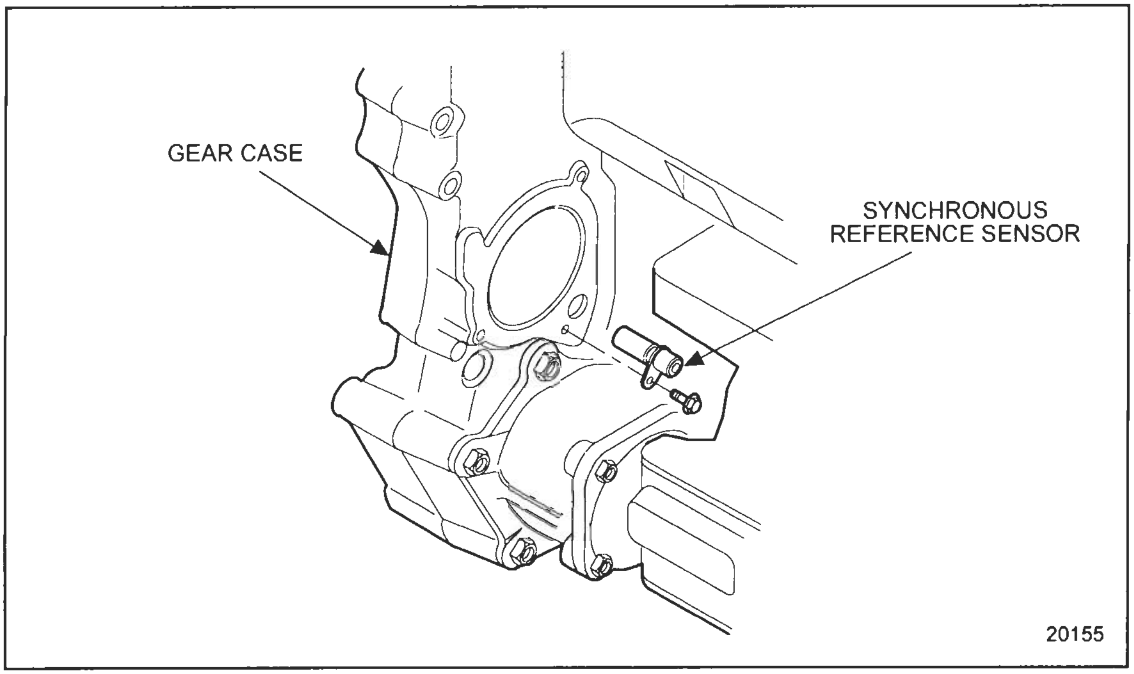


Figure 2–60 SRS Location

NOTE:
The length of the SRS sensor element is 33.16–33.66 mm (1.305–1.325 in.).

The sensor portion of the SRS extends through a hole in the gear case, and is positioned very near the rear of the bull gear. A bolt, inserted through a hole in the SRS bracket, secures the SRS assembly to the gear case. The SRS connector is black in color.

The SRS sends a signal to the ECM. This signal is generated by a raised metal pin on the rear of the bull gear. See Figure 2-61.

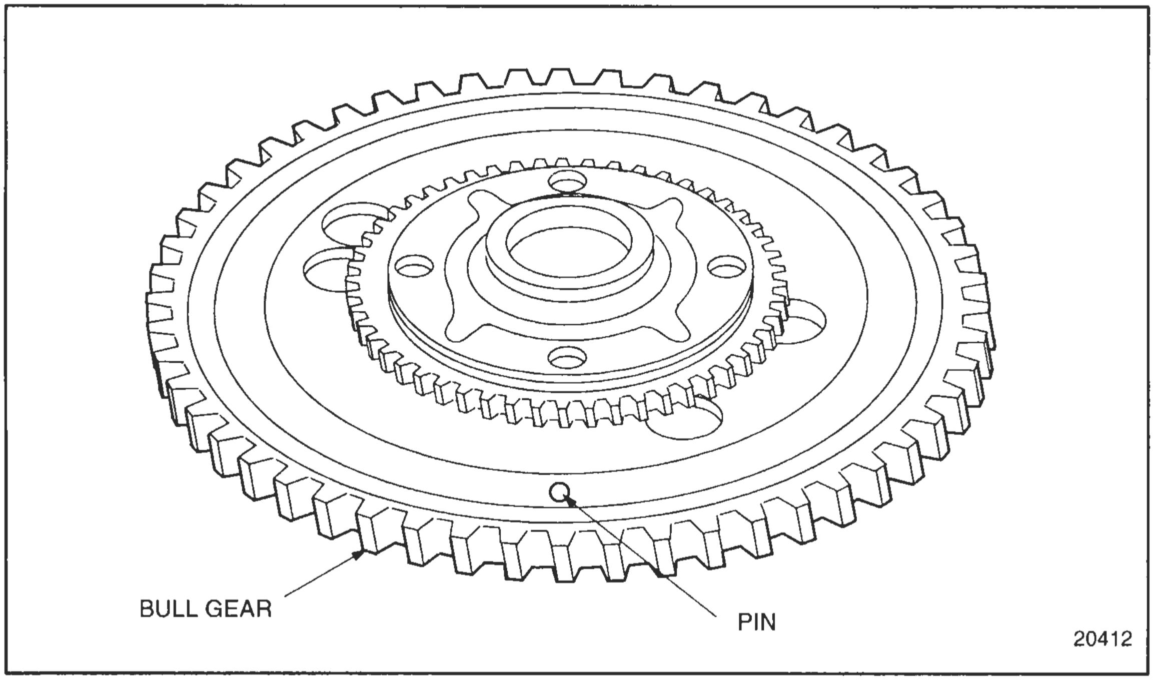


Figure 2–61 Bull Gear

The bull gear pin passes by the SRS as the number one piston reaches approximately 45 degrees before Top-Dead-Center. This information is used by the ECM to determine engine speed.

2.15.1 Repair or Replacement SRS

The SRS is a non–serviceable item and is replaced as a unit. No adjustment is required.

2.15.2 Removal of SRS

Remove the SRS as follows:

1. Disengage the locking tang on the SRS connector. Grasp the connector bodies and gently pull them apart.
2. Using a socket and long extension, remove the SRS bolt.
3. Remove the SRS by pulling it straight out of the gear case.

2.15.3 Installation of SRS

Install the SRS as follows:

1. The SRS is an electronic component. Use care upon installation. The O–ring on the sensor may be coated with clean engine oil for ease of installation.
2. Insert the SRS into the gear case and index the hole in the bracket with the hole in the gear case.
3. Insert the SRS bolt and tighten it to 30–38 N·m (22–28 lb·ft) torque.
4. Plug the connectors together, making sure the locking tang clicks into place.
5. Turn the ignition to the "ON" position. If any diagnostic code other than 25 appears, refer to the *DDEC Troubleshooting Guide,* 6SE489 (DDEC II), or Series 50 Troubleshooting Manual, 6SE494.

2.16 TIMING REFERENCE SENSOR

The Timing Reference Sensor (TRS) is an electronic component that is mounted to the left side of the gear case, near the crankshaft centerline. See Figure 2-62.

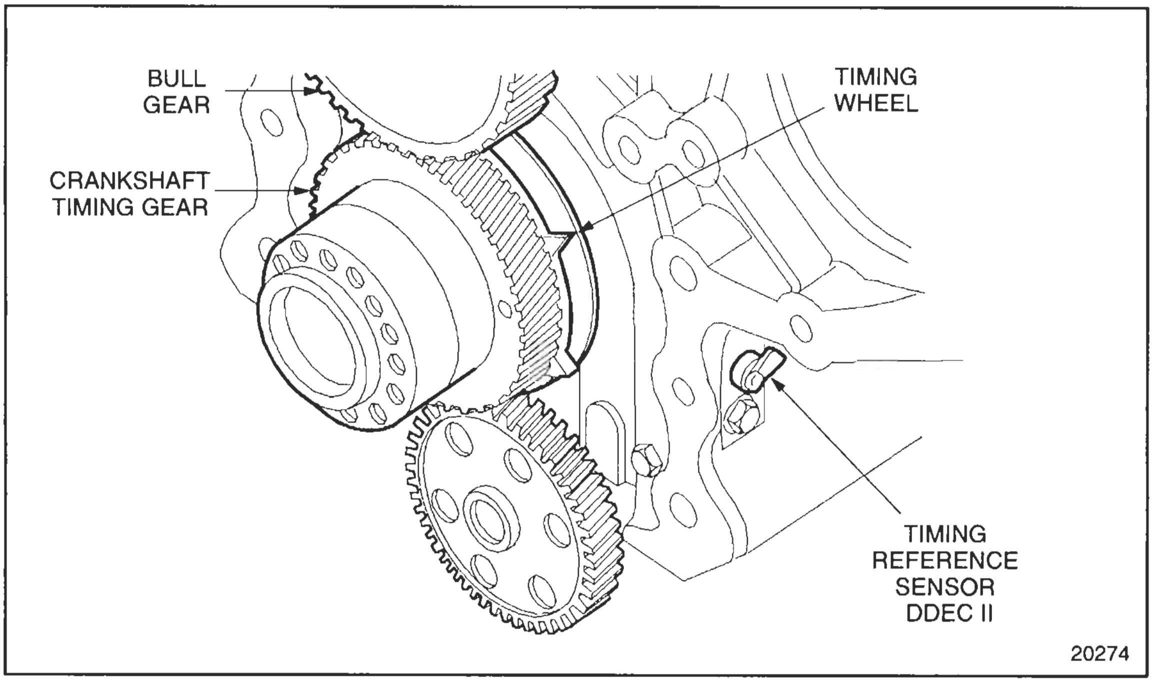


Figure 2–62 TRS and Related Parts

NOTE:
The length of the TRS sensor element is 56.08–56.58 mm (2.207–2.227 in.).

The sensor portion of the TRS extends through an opening in the gear case, and is positioned near the teeth of the timing wheel. A bolt, inserted through a hole in the TRS bracket, secures the TRS assembly to the gear case. The TRS connector is gray in color.

The TRS sends a signal to the ECM. This signal is generated by a series of evenly spaced teeth on the timing wheel. As the timing wheel rotates with the crankshaft, a tooth passes by the TRS as each cylinder reaches 10 degrees before Top-Dead-Center. These signals are used by the ECM to determine injector solenoid operation times.

2.16.1 Repair or Replacement of TRS

The TRS is a non-serviceable component and is replaced as a unit. No adjustment is required.

2.16.2 Removal of TRS

Remove the TRS as follows:

1. Disengage the locking tang on the TRS connector. Grasp the connector bodies and gently pull them apart.
2. Remove the bolt that secures the TRS to the gear case.
3. Remove the TRS by pulling it straight out of the gear case.

2.16.3 Installation of TRS

Install the TRS as follows:

1. The TRS is an electronic component. Use care upon installation. The O-ring on the sensor may be coated with clean engine oil for ease of installation.
2. Insert the TRS into the gear case and index the hole in the bracket with the hole in the gear case.
3. Insert the TRS bolt and tighten it to 30–38 N·m (22–28 lb·ft).
4. Plug the connectors together, making sure the locking tang clicks into place.
5. Turn the ignition to the "ON" position. Observe or read any diagnostic codes. If any code other than 25 appears, refer to the *DDEC Troubleshooting Guide,* (DDEC II) 6SE489, or *Series 50 Troubleshooting Manual*, 6SE494.

2.17 COOLANT LEVEL SENSOR

The Coolant Level Sensor (CLS) is a two-piece sensor. See Figure 2-63. The sensor probe (supplied by the vehicle manufacturer) is mounted in the top tank or overfill tank. The sensor module is mounted on the vehicle. The module sends an electrical signal to the ECM to indicate coolant level. Low coolant will activate the stop engine function or warning function.

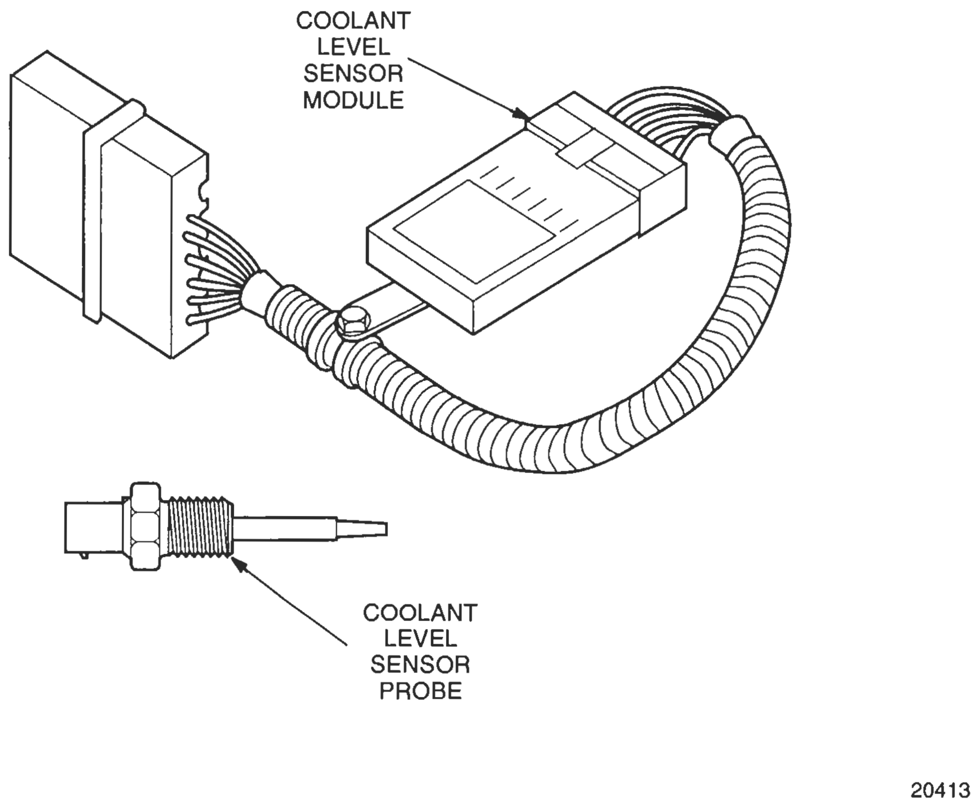


Figure 2-63 Two-piece Coolant Level Sensor (CLS)

2.17.1 Repair or Replacement of CLS

Both the CLS probe and module are non-serviceable and should be replaced as necessary.

2.17.2 Removal of CLS

Remove the CLS as follows:

1. Open the drain cock at the bottom of the radiator and drain the coolant into an appropriate container. Remove only as much coolant as is necessary to clear the CLS probe.
2. Remove ground wire screw and ground wire from side of probe. Loosen and remove nut from sensor lead of probe. Remove sensor lead, or unplug the two-pin connector.
3. Use the appropriate wrench on the hex portion of the sensor and unscrew it from the radiator.

2.17.3 Installation of CLS Probe

Install the CLS Probe as follows:

1. Reverse procedure for installation.
2. Refer to section 4 and fill the cooling system.
3. Turn the ignition to the "ON" position. Observe or read any diagnostic codes. If any code other than 25 appears, refer to the *DDEC Troubleshooting Guide*, 6SE489 (DDEC II) or *Series 50 Troubleshooting Manual*, 6SE494.
4. Start the engine and check for leaks.

2.17.4 Removal of CLS Module

Remove the CLS Module as follows:

1. Disengage the locking tang on the CLS module connector. Grasp the connector bodies and gently pull them apart.
2. Remove module from vehicle.

2.17.5 Installation of CLS Module

Install the CLS Module as follows:

1. The CLS module is an electronic component. Use care upon installation.
2. Insert the CLS module.
3. Engage locking tang on CLS module connector.

2.18 FUEL PRESSURE SENSOR

The Fuel Pressure Sensor (FPS) is installed into the secondary fuel filter. See Figure 2–64. The FPS is not used in all applications. The FPS sends an electrical signal to the ECM telling it what the engine fuel pressure is at any given speed.

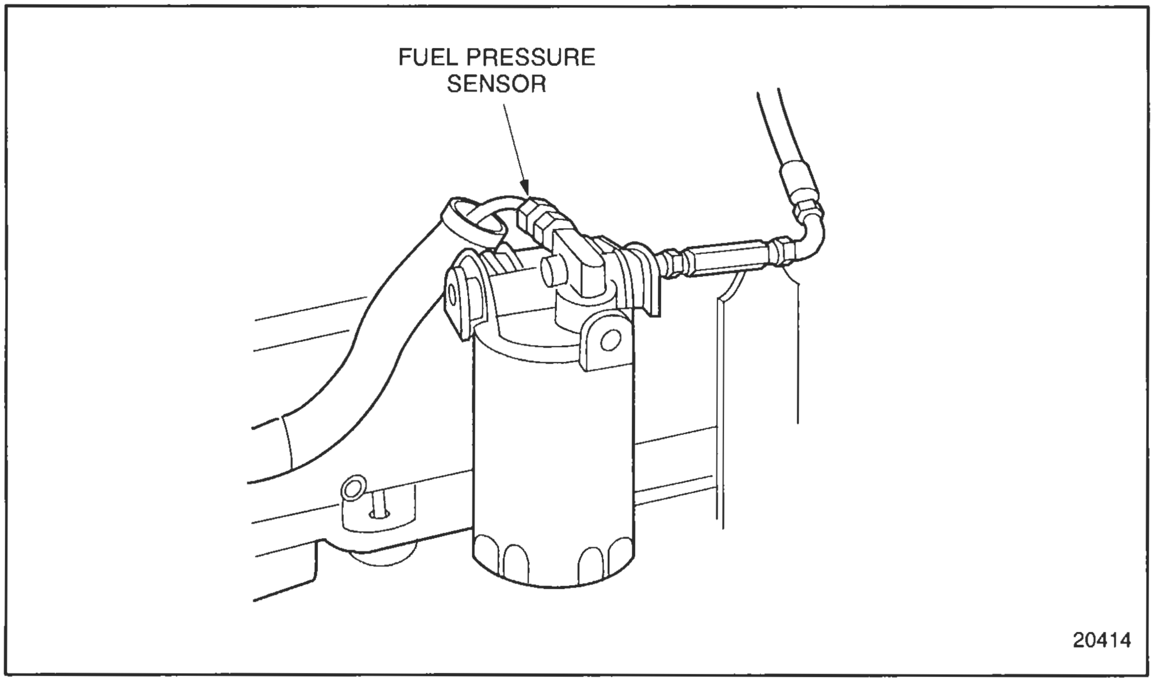


Figure 2–64 Engine Fuel Pressure Sensor

2.18.1 Repair or Replacement of FPS

The FPS is non–serviceable and should be replaced as a unit. No adjustment is required.

2.18.2 Removal of FPS

Remove the FPS as follows:

1. Disengage the locking tang on the three–wire connector. Grasp the body of the connector and gently pull it free of the FPS.
2. Use the appropriate wrench on the hex end of the FPS to unscrew it from the filter.

2.18.3 Installation of FPS

Install the FPS as follows:

1. The FPS is an electrical device. Use care on installation
2. Use Loctite Pipe Sealant with Teflon, J 26558–92 (or equivalent) on all but the first two threads of the FPS to prevent leaks.
3. Screw FPS into the filters.
4. Turn the ignition to the "ON" position. If any diagnostic code other than 25 is obtained, refer to the *DDEC Troubleshooting Guide*, 6SE489 (DDEC II), *Series 50 Troubleshooting Manual*, 6SE494.

2.19 FUEL TEMPERATURE SENSOR

The Fuel Temperature Sensor (FTS) is installed into the secondary fuel filter. See Figure 2-65. The FTS sends an electrical signal to the ECM indicating fuel inlet temperature. The ECM uses this information to calculate fuel consumption.

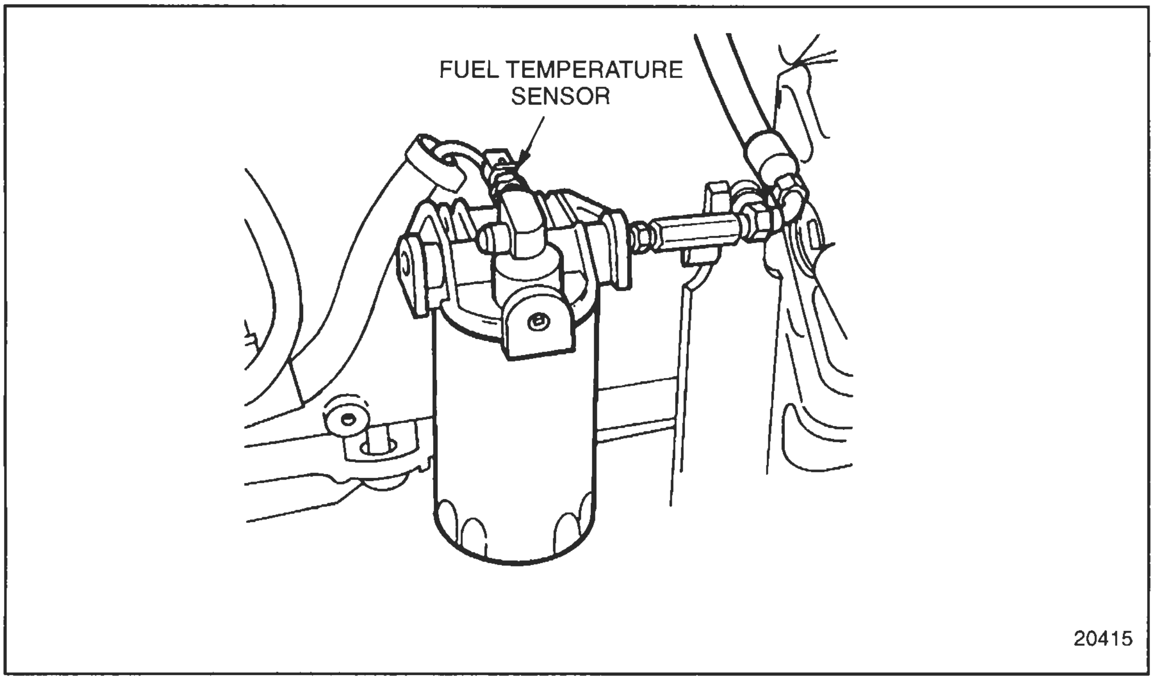


Figure 2-65 Engine Fuel Temperature Sensor

2.19.1 Repair or Replacement of FTS

The FTS is non-serviceable and should be replaced as a unit. No adjustment is required.

2.19.2 Removal of FTS

Remove the FTS as follows:

1. Disengage the locking tang on the two-wire connector. Grasp the body of the connector and gently pull it from the socket.
2. Use the appropriate wrench on the hex portion of the sensor and unscrew it from the fitting.

2.19.3 Installation of FTS

Install the FTS as follows:

1. The Fuel Temperature Sensor is an electrical device. Use care in the installation process.
2. Use Loctite Pipe sealer with Teflon J 26558-92 (or equivalent) on all but the first two threads of the FTS to prevent leaks.
3. Screw FTS into the fitting.
4. Engage the locking tang.
5. Turn the ignition to the "ON" position. Observe or read any diagnostic codes. If any code other than 25 is obtained, refer to the *Series 50 Troubleshooting Manual*, 6SE489 (DDEC II), or *Series 50 Troubleshooting Manual*, 6SE494.

2.A GENERAL INFORMATION

Section **Page**

SHOP NOTES

The following shop notes describe flexible fuel lines and their installation.

Fuel Lines

Flexible fuel lines are used to facilitate connection of lines leading to and from the fuel tank, and to minimize the effects of any vibration in the installation.

An .080 in. (2.0 mm) restricted orifice is incorporated in the fuel return fitting (upper fitting) at the rear of the cylinder head to maintain fuel pressure in the cylinder head. Do not use restricted fittings anywhere else in the fuel system, and do not substitute a standard fitting for the restricted fitting.

The .080 in. (2.0 mm) restricted orifice is designed to provide the proper fuel system pressure under all conditions. Do not alter or substitute another size since this may alter engine performance and emissions.

When installing fuel lines, it is recommended that connections be tightened only sufficiently to prevent leakage of fuel; thus flared ends of the fuel lines will not become twisted or fractured because of excessive tightening. After all fuel lines are installed, run the engine long enough to determine if all the connections are sufficiently tight. If any leaks occur, tighten the connections only enough to stop the leak. Also check that the fuel filters are tight against the filter adaptors. Do not overtighten filters.

High fuel temperatures can cause low power and reduced fuel economy.

Detroit Diesel requires that all OEM's follow special fuel line configuration requirements to eliminate high fuel temperature concerns. Some of these configurations are as follows:

1. A dual draw/dual return style fuel line system should be used with vehicles having dual fuel tank configurations.
2. When a single tank with a 75 gallon (284 L) or greater capacity is employed, the return and supply line should be at opposite ends of the tank.
3. When a single tank with less than a 75 gallon (284 L) capacity is used, a fuel cooler is required on the spill side of the fuel system. The fuel cooler should be sized to allow a 40° F (22.2° C) temperature drop under the following conditions with a 1.5 gal/min (5.7 L/min) flow rate:

Temperature Drop Conditions

- ❑ 110° F (61° C) Maximum Ambient
- ❑ 180° F (100° C) Fuel Temperature into Cooler

The return fuel line must be connected to the top or face of the fuel tank opposite the pick–up line. The fitting should spray the returning fuel along the inside wall of the tank or onto the surface of the fuel to dissipate as much heat as possible. Returning fuel to the bottom of the fuel tank or using a stand pipe is not permitted.

In addition, the fuel return line should be designed to prevent air from bleeding back into the cylinder head fuel passages after the engine is shut down. The possible configurations for this are a looped fuel line or the addition of a fuel check valve (23509140) in the fuel return line. See Figure 2-66.

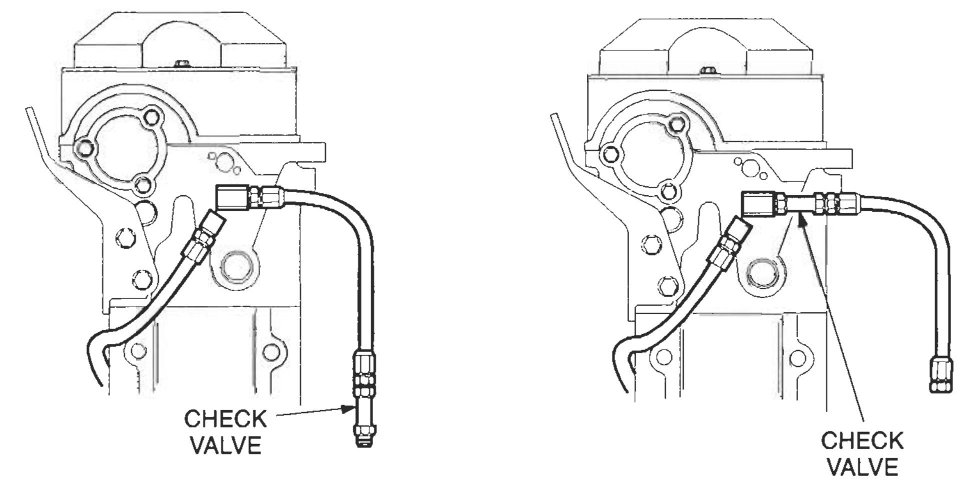


Figure 2–66 Fuel Return Check Valve

SPECIFICATIONS

Specifications are listed in the General Information section at the beginning of the manual. Exceptions are listed below:

Exceptions to Standard Fastener Torque Specifications

Exceptions to Standard Fastener Torque Specifications supporting the Series 50 Engine are listed in Table 2-8 and also listed in Table 2-9.

Fastener	Size	Torque, N·m	Torque, lb·ft
Bolt, Injector Clamp	M10 x 1.5	58–66	43–49

Table 2–8 Exceptions to Standard Fastener Specifications

Fastener	Size	Torque, N·m	Torque, in.·lb
Bolt, Turbo Boost Sensor–to–inlet	M5 x 0.8	2.4–3.0	21–26
Screw, Harness Connector–to–EDU	#10–24	2.4–3.0	21–26
Screw, Harness Connector–to–ECM	#10–24	2.4–3.0	21–26
Screw, Injector Wire Connector	M3 x 0.5	1.4–2.0	12–17

Table 2–9 Exceptions to Standard Fastener Torque Specifications

SERVICE TOOLS

Listed in Table 2-10 are the service tools used in this section.

Tool Number	Tool Name
J 1508–8	Oil Seal Installer–Handle
J 1508–13	Oil Seal Remover
J 22273–01	Cylinder Liner Depth Gage (used as sled gage)
J 22775	Fuel Filter Wrench
J 25359–11	No. E–8 Torx Socket
J 26558–92	Pipe Sealant
J 33021–A	Seal Protector
J 33853	Fuel Pump Needle Bearing Remover
J 33854	Fuel Pump Needle Bearing Installer
J 33880	Injector Tube Installation/Removal Tool Set
J 33880–1	Seat Reamer
J 33880–3	Large Bushing
J 33880–4	Tube Installer
J 33880–5	Tip Reamer
J 33880–7	Protrusion Gage
J 33880–10	Small Bushing
J 33880–20	Gage Block
J 34158	Oil Seal Installer Adaptor
J 34760	Injector Pop–N–Fixture
J 35751	Diagnostic Jumper Wire Kit
J 36500	DDEC II Diagnostic Reader
J 38500–D	DDEC II, III Diagnostic Reader
J 38767	Barnes Fuel Pump Service Kit
J 38767–1	Fuel Pump Holding Fixture
J 4880	Snap Ring Pliers (External)
J 5286–5	Pilot
J 5286–6	Injector Tube Flaring Tool
J 5286–8	Tube Tip Refinisher Tool
J 7944	Brass Wire Buffing Wheel (injector spray nozzle)

Table 2–10 Service Tools Supporting Series 50 Engines

3 LUBRICATION SYSTEM

3.1 OVERVIEW OF LUBRICATING SYSTEM

The lubrication system consists of the following components:

- ❑ Oil pump
- ❑ Pressure regulator valve
- ❑ Pressure relief valve
- ❑ Oil filters
- ❑ Oil filter adaptor
- ❑ Oil cooler
- ❑ Oil level dipstick
- ❑ Oil pan
- ❑ Ventilating system

A schematic of the lubricating system is shown in the following illustration. See Figure 3–1.

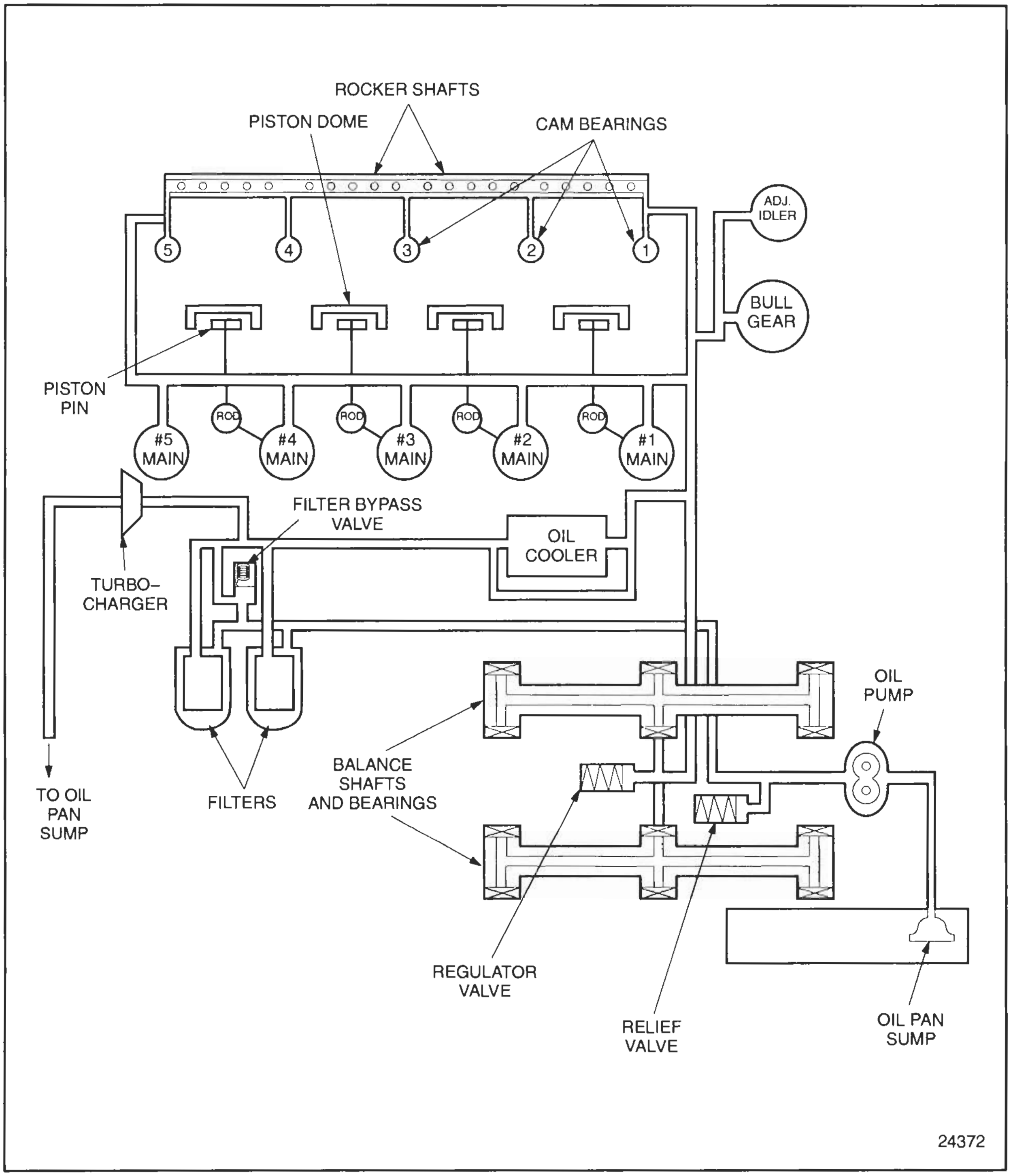


Figure 3–1 Schematic Diagram of Current Lubrication System

The lubricating oil is circulated by a gear–type pressure pump mounted to the front bulkhead of the balance support and gear driven front the crankshaft through the balance shaft idle gear.

Clean engine oil is assured at all times by the use of 2 spin–on type, full flow oil filters incorporated in the engine lubrication system. These filters, which are installed in the lubrication system between the pump and the cooler, filter all of the oil before it enters the engine.

Oil leaving the pump is forced through full flow filters to the oil cooler and bypass passage and then into the oil gallery in the cylinder block from where it is distributed to the various engine bearings and moving parts. The oil then drains from the cylinder head and other engine parts return oil back to the oil pan.

A spring–loaded, integral plunger–type relief valve, attached to the balance support, bypasses excess oil from the discharge back to the oil pan when the pressure in the oil pump exceeds approximately 690 kPa (100 $lb/in.^2$).

If the oil cooler should become clogged, the oil will flow from the pump through a drilled passage directly into the oil gallery.

Stabilized oil pressure is maintained within the engine at all speeds, regardless of the oil temperature, by means of a regulator valve also attached to the balance support. When the oil pressure at the valve exceeds 380 kPa (55 $lb/in.^2$), the regulator valve opens and remains open until the pressure is less than the opening pressure.

Oil from the cooler is directed to a longitudinal main oil gallery on the cooler side of the cylinder block. See Figure 3–1. This gallery distributes the pressurized oil to the main bearings and to a horizontal, transverse passage at each end of the cylinder block. From each of these two horizontal passages, oil flows into two vertical bores (one at each end of the cylinder block) to vertical passages in the cylinder head. These passages in the cylinder head deliver oil from the cylinder block to the No. 1 and 5 lower camshaft bearing saddles. From there, the oil is directed upward (through the enlarged stud hole) to the No. 1 and 5 upper camshaft bearing caps. A drilled passage in each of these caps exits at the rocker arm shaft seat area, where it indexes with a hole in each rocker arm shaft. The rocker arm shafts have internal oil passages that deliver oil to the rocker arm bushings and intermediate upper camshaft bearings. Some of the oil supplied to the rocker arm bushing passes through the oil hole in the bushing to the injector arm. The injector rocker is drilled to supply oil to the fuel injector follower and splash oil on the camshaft follower roller, adjuster screw, valve buttons, retainer clips intake and exhaust valve stems. The No. 3 camshaft cap is "Y" drilled, forming an oil path connection between the front and rear rocker arm shafts, to ensure complete lubrication. The oil then drains through passages in the cylinder head and block, and back to the oil pan.

Oil for lubricating the connecting rod bearings, piston pins and for cooling the piston dome is provided through the drilled crankshaft from the adjacent forward main bearings.

Two holes in the bull gear recess area of the cylinder block are drilled into the cylinder block front–cross oil gallery. These holes supply oil to the bull gear bearings, bull gear, and camshaft idler gear and hub. See Figure 3–2.

Excess oil from the bull gear lubricates the crankshaft timing gear, and oil pump drive gear, and balance shaft gear. A hole at the top, front of the block, is drilled into the block front–cross oil gallery, which mates with an oil passage in the gear case that directs oil to the adjustable idler gear assembly. See Figure 3–2. Excess oil from the adjustable idler gear lubricates the accessory drive and water pump drive gears. The bearings and shafts of these two drive assemblies are splash–fed oil through holes in their housings.

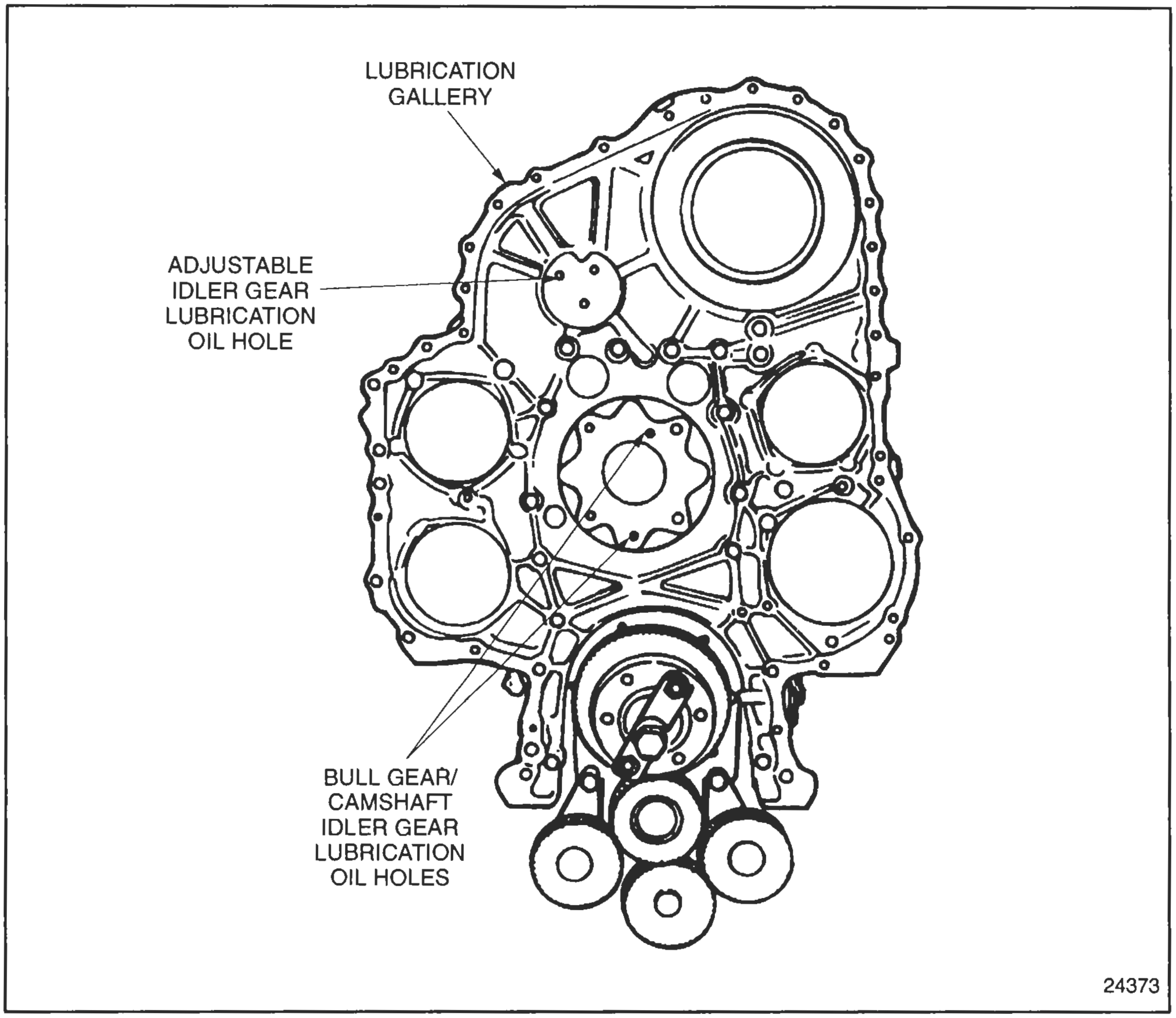


Figure 3–2 Gear Train Oil Supply Holes

A flexible, external oil line runs from a threaded hole at the top, front corner of the left side of the cylinder block, which is tapped into the main oil gallery. The flexible line runs to a fitting at the air compressor assembly.

Oil drains from the air compressor through a hole in the air compressor drive housing into the gear case.

A flexible, external oil line feeds oil from the oil filter adaptor housing pressure gallery, to the turbocharger bearings and shaft. This oil is returned through an external line to the block near the block–to–oil pan split line, and then back to the oil pan.

Series 50 engines use red dye to detect lube oil system leaks during engine testing at the factory. Customers receiving new engines may notice some residual dye remaining in the lube oil systems. This dye should be quickly dispersed after the first few hours of engine operation, and will have no detrimental effect on the engine.

3.2 OIL PUMP

The gear-type oil pump, see Figure 3-3, is mounted to the front bulkhead of the balance support and is gear driven from the front end of the crankshaft through the oil pump idler gear.

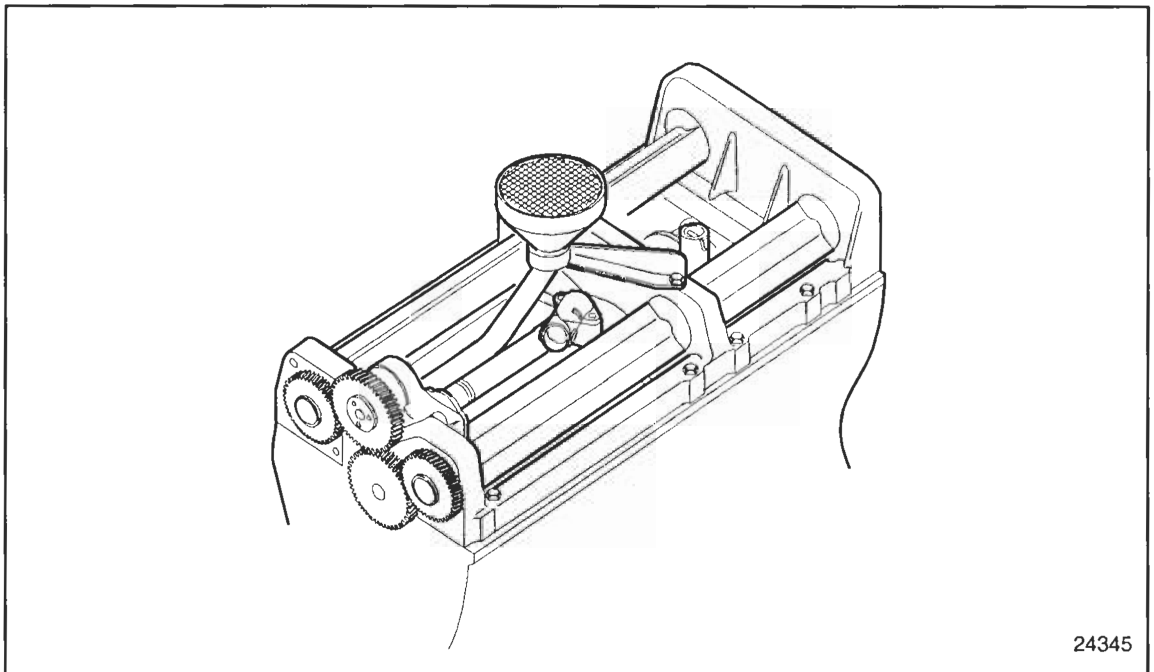
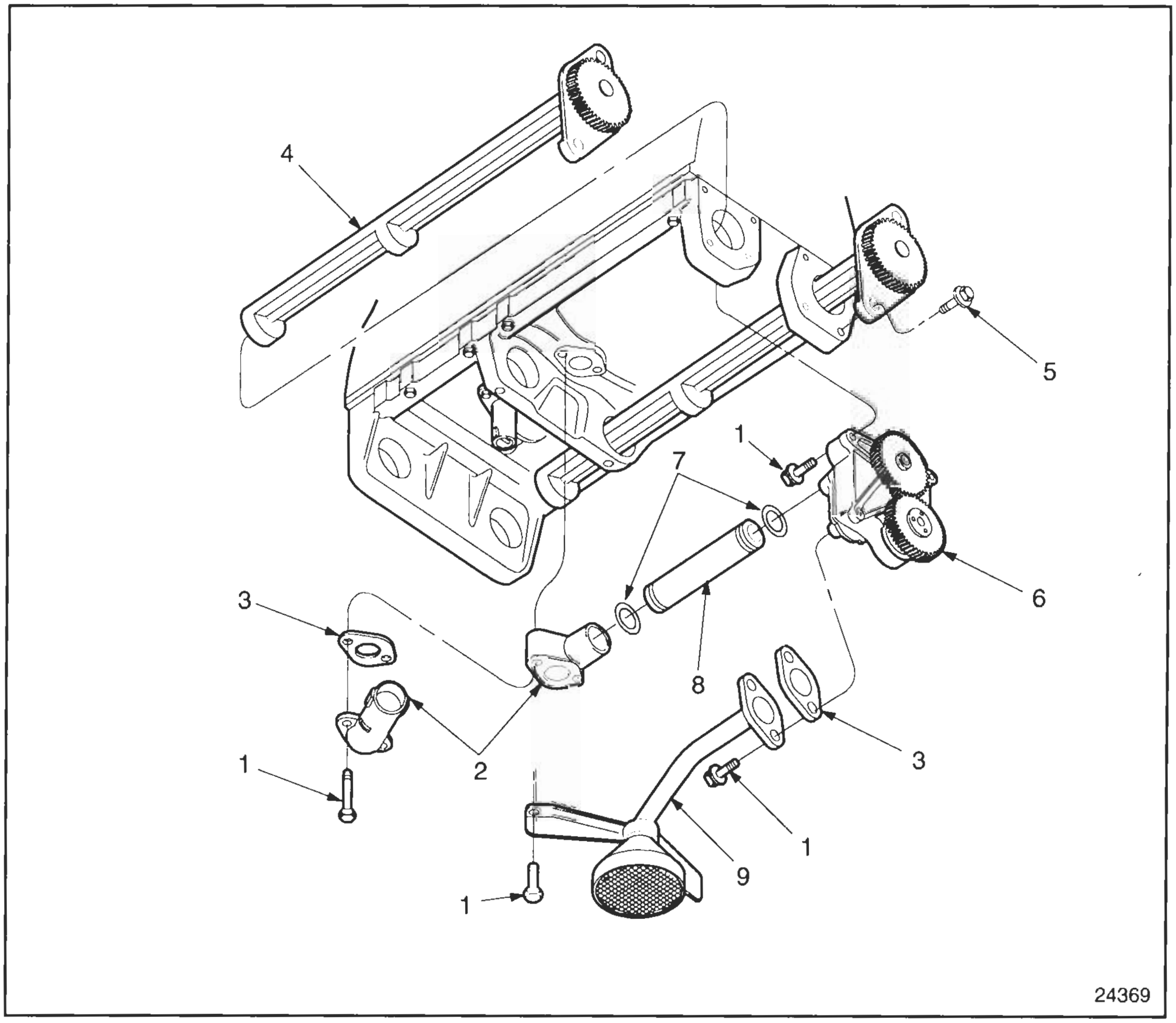


Figure 3-3 Oil Pump Mounting

The drive gear is pressed on the driveshaft, which is supported inside the housing on two bushings. The driven gear is pressed on the driven gear shaft, which is supported inside the housing on two bushings.

A plunger-type relief valve is attached to the adaptor at the end of the oil supply tube. The relief valve bypasses oil back to the pan when the pressure in the pump exceeds 725 kPa (105 lb/in.^{2}).

The oil pump helical gears rotate inside a housing. See Figure 3–4.



1. Bolt
2. Relief Valve and Adaptor
3. Gasket
4. Balance Shaft Assemblies
5. Thrust Plate Bolt
6. Oil Pump Assembly
7. O–rings (2)
8. Oil Feed Tube
9. Pick–up Tube and Brackets

Figure 3–4 Oil Pump and Parts Components

An inlet pipe assembly, with screen, is attached to the inlet opening in the pump body. The screen end of the inlet pipe assembly is supported with brackets mounted to the balance support.

The inlet screen is located below the oil in the pan and serves to strain out any foreign material which might damage the pump.

3.2.1 Repair or Replacement of Oil Pump

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3–5.

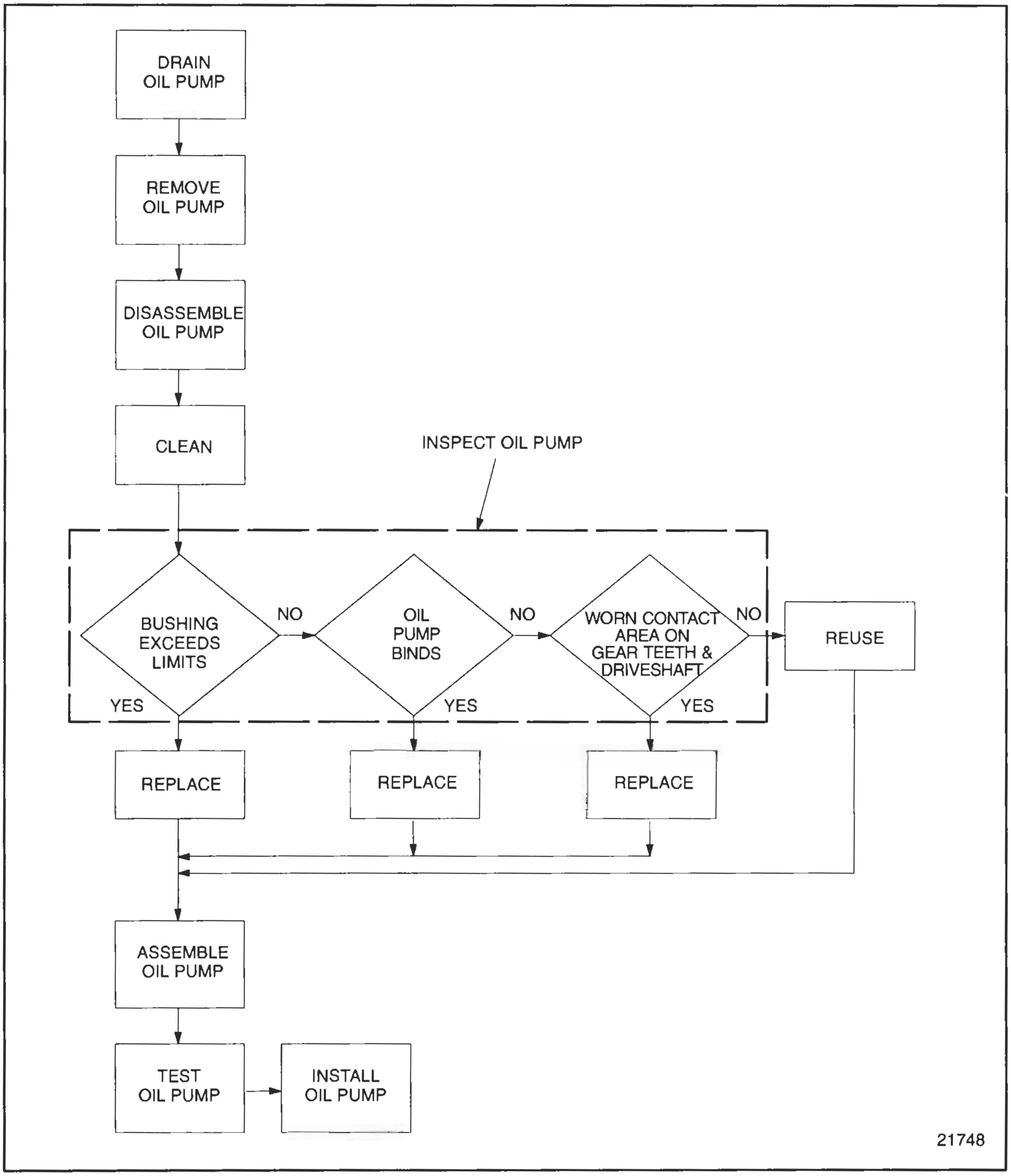


Figure 3–5 Flowchart for Repair or Replacement of Oil Pump

3.2.2 Cleaning and Removal of Oil Pump

Precleaning is not necessary to remove the oil pump.

To remove the oil pump, refer to section 1.27.2.

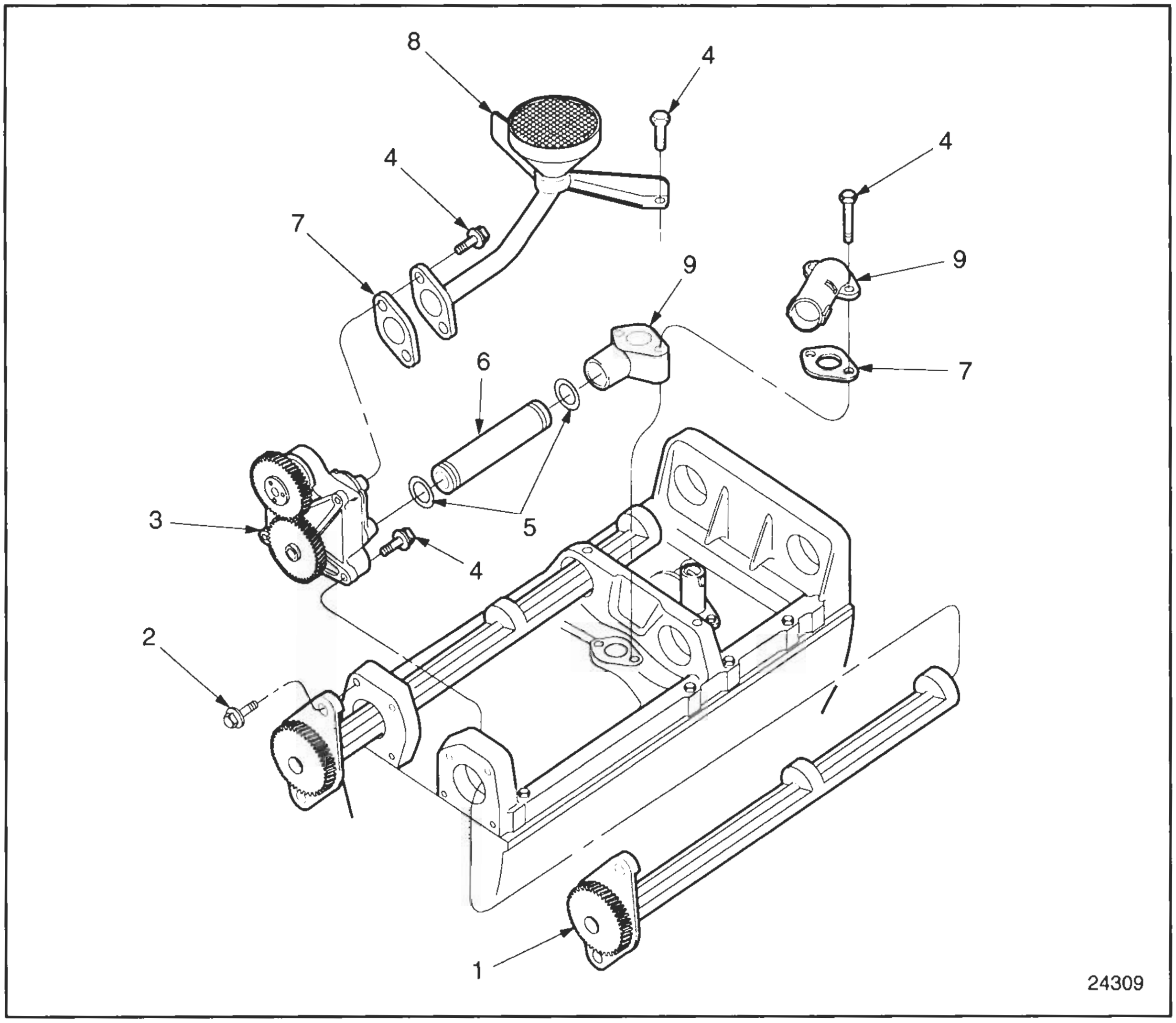
3.2.3 Disassembly of Oil Pump

Observe the position of all parts including the oil pick–up tube and outlet pipe during disassembly to facilitate reassembly of the pump.

Disassemble the oil pump as follows:

1. Set cylinder No. 1 at top dead center by barring the engine over until the piston reaches the top of the cylinder. The cylinder will then be at top–dead–center (TDC).
2. Drain the engine oil. Refer to section 13.5.1.
3. Remove the oil pan. Refer to section 3.9.2.

4. Remove the two bolts that fasten the oil suction tube braces to the balance support. See Figure 3-6.



1. Balance Shaft Assembly
2. Thrust Plate Bolt
3. Oil Pump Assembly
4. Bolt
5. O-Rings
6. Oil Feed Tube
7. Gasket
8. Pick-up Tube and Bracket
9. Regulator Valve and Adaptor

Figure 3-6 Oil Pump Removal

5. Remove the bolts that attach the suction tube flange to the oil pump body and remove the pick–up tube assembly.
6. Install the oil pump gear holding tool J 39816.
7. Support the balance shaft assembly on the center and front bulkhead using tool J 39814.
8. Remove the nine bolts that fasten the balance assembly to the cylinder block and lower the assembly.
9. Lift the balance assembly from the transmission stand, turn it over and set it on a clean working surface using care not to damage the locating dowels.

3.2.3.1 Inspection of Oil Pump

Inspect the pump as follows:

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

1. Wash all parts in clean fuel oil and dry with compressed air.
2. Inspect the bushings in the pump body and cover.
   [a] The shaft–to–pump cover bushing clearance should not exceed 0.089 mm (.0035 in.).
   [b] If clearance exceeds 0.089 mm (.0035 in.), replace bushing.

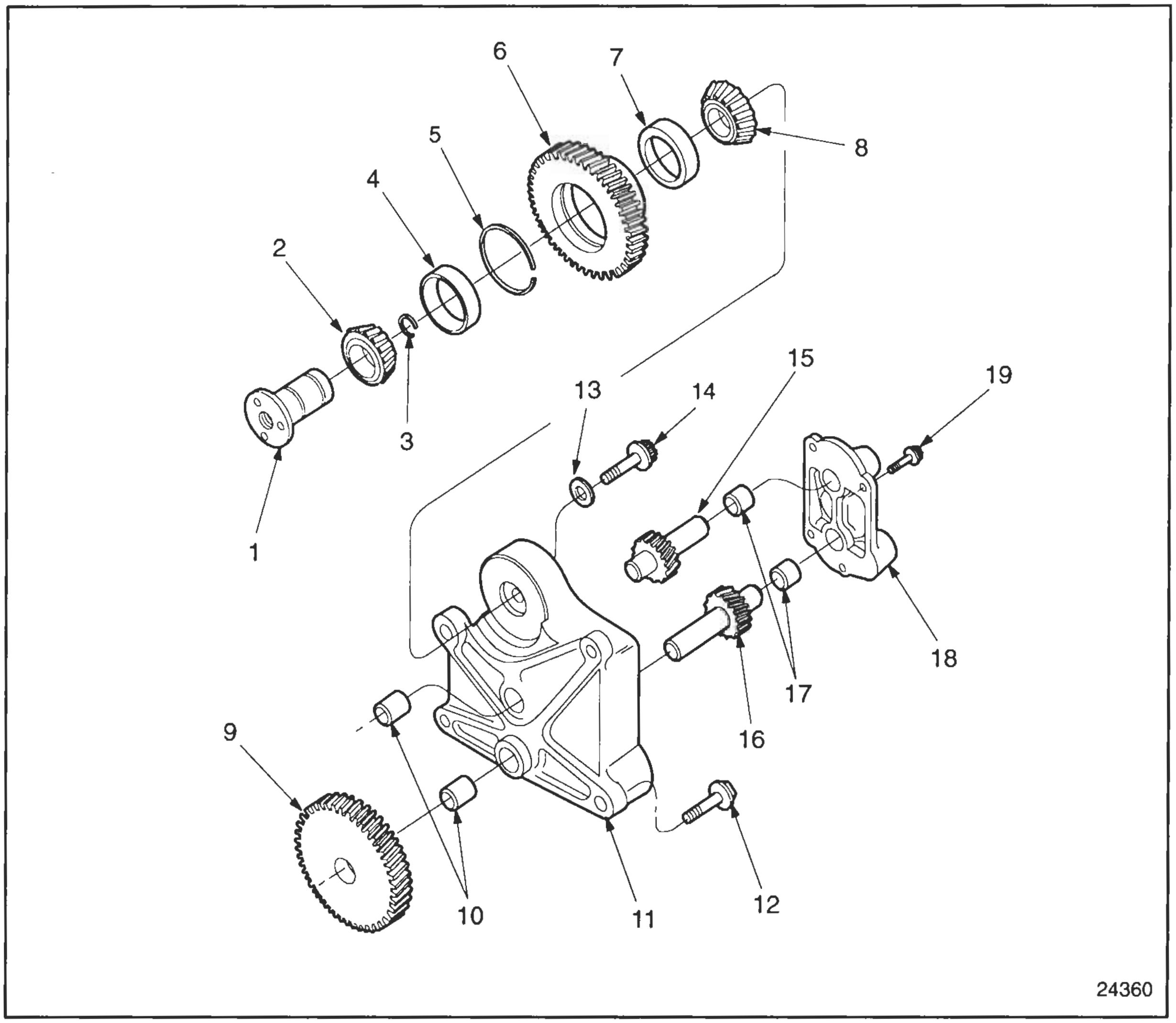
NOTICE:

The use of excessively worn gears will result in low engine oil pressure which, in turn, may lead to serious engine damage.

3. Inspect the oil pump gears.
   [a] Check to see if the gears turn freely in the pump housing.
   [b] If gear binds, replace it with a new gear.
4. Inspect gear teeth and driveshaft bushing contact areas.
   [a] Check for worn or scored contact areas on gear teeth and driveshaft.
   [b] If area is worn scored, replace gear and driveshaft assemblies with new parts, or replace the complete pump assembly.

3.2.4 Assembly of Oil Pump

Assemble the oil pump as follows: See Figure 3–7.



1. Oil Pump Idler Shaft
2. Oil Pump Bearing
3. Snap Ring
4. Bearing Race
5. Snap Ring
6. Oil Pump Idler Gear
7. Oil Pump Idler Gear Bushing
8. Oil Pump Bearing
9. Oil Pump Drive Gear
10. Oil Pump Body Bushing
11. Oil Pump Body
12. Oil Pump Body Bolt
13. Washer
14. Oil Pump Body Bolt
15. Oil Pump Shaft Gear
16. Oil Pump Shaft Gear
17. Oil Pump Body Bushing
18. Oil Pump Body Cover
19. Bolt

Figure 3–7 Oil Pump Assembly

1. Lubricate the driveshaft bushing with clean engine oil.
2. Insert the driveshaft and gear assembly into the pump body. See Figure 3-7.
3. Position the oil pump assembly on a press, pump body down, supporting the driveshaft. The pump body should be free of the press bed supported by the pump gear contacting the bottom of the pump cavity.
4. Coat the bore of the drive gear with a light film of Lubriplate (or equivalent).
5. Position drive gear squarely on the end of the shaft.
6. Press the drive gear onto the shaft with timing mark side outside until a clearance of 1.00 mm (.039 in.) is obtained between the inner face of the gear and the pump body. See Figure 3-8.

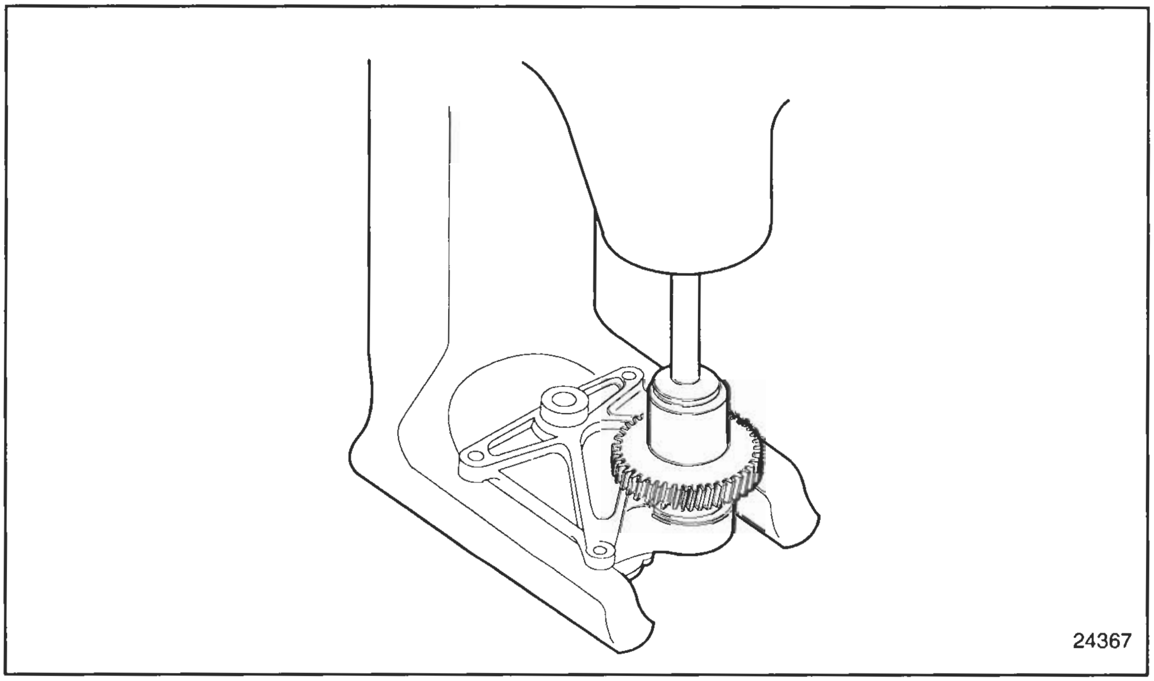


Figure 3–8 Oil Pump Drive Gear Installation

NOTE:
A minimum press load of 8.8 kN (1,978 lb) must be obtained when pressing the gear onto the shaft. When completed, an end play of 0.85–1.15 mm (.033–.044 in.) must be obtained.

7. Lightly coat the driven gear bushing with clean engine oil.
8. Insert the driven shaft and gear assembly into the pump body.
9. Lightly coat both bushings in the pump cover with clean engine oil.
10. Index them with the shafts.
11. Install the four cover bolts, hand tighten.
12. Rotate the oil pump by hand. The oil pump must turn freely without binding.

NOTICE:
The cause of oil pump binding must be corrected before installation is complete or severe engine damage may result.

13. If binding occurs, stop assembly and disassemble until the cause can be detected and corrected. Refer to section 3.2.3.
14. Tighten the four cover bolts to 30–38 N·m (22–28 lb·ft).

3.2.4.1 Test Assembled Oil Pump

Test oil pump as follows:

1. Rotate the pump by hand.
   [a] Check for binding.
   [b] If binding occurs, disassemble oil pump again. Refer to section 3.2.3.
2. With a dial indicator mounted on the pump mounting surface, rotate the gear and check the gear runout. See Figure 3–9.

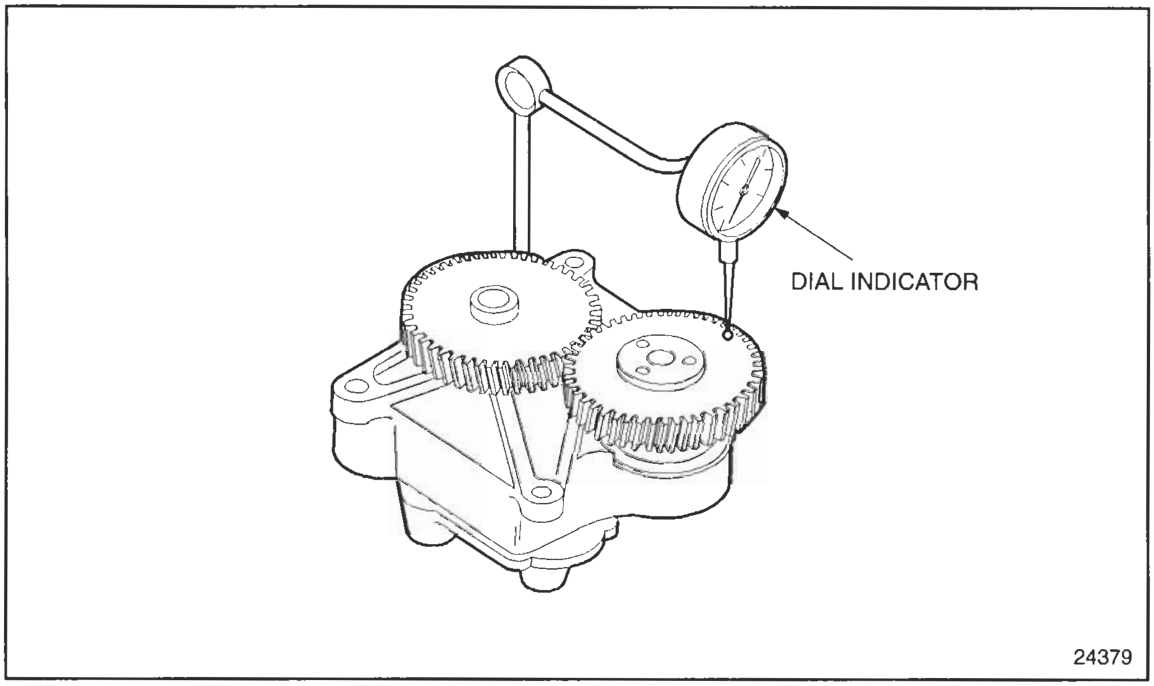


Figure 3–9 Gear Runout Measurement

   [a] The runout may not exceed 0.05 mm (.002 in.).
   [b] If runout exceeds 0.05 mm (.002 in.), disassemble oil pump. Refer to section 3.2.3.

After testing is completed, finish assembly of oil pump as follows:

1. Press cups in idler gear to snap ring.

NOTE:
Tool J 39769 is a holding tool only. Do not torque.

2. Install the idler gear, shaft, and tapered roller bearings cone and spacer in the pump housing.
3. Align the teeth of the idler gear, so that the "Y" on the gear and the "Y" on the drive gear are aligned.
4. Using tool J 39769, hold the shaft in place, and torque the left–hand threaded bolt to 200–230 N·m (147–170 lb·ft).

5. Check the gear lash between gears. Lash should read 0.051–0.203 mm (.002–.008 in.). See Figure 3–10.

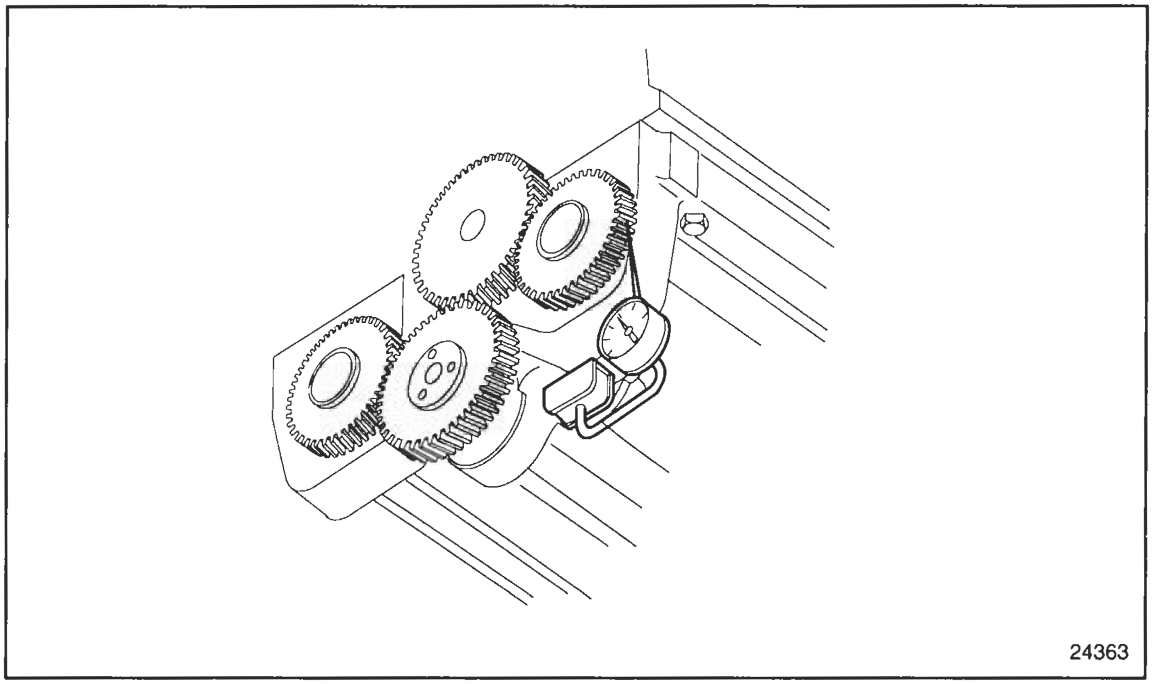


Figure 3–10 Checking Gear Lash

3.2.5 Installation of Oil Pump

Perform the following steps to install the oil pump:

1. Install the oil pump, taking care to match each of the letters stamped on the oil pump idler gear and oil pump drive gear with the same letter of the left and right side balance shafts. See Figure 3-11.

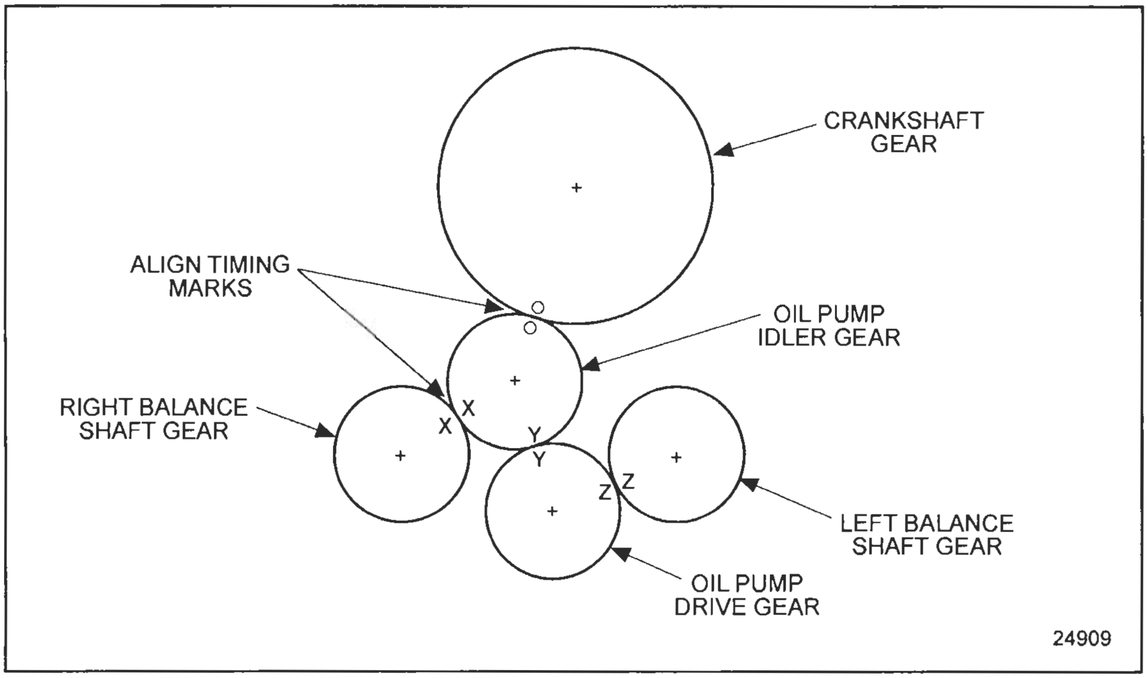


Figure 3-11 Balance Shaft Drive Gear Timing

2. When all the gears are aligned correctly, install the M8 bolts and torque to 25 lb·ft (34 N·m).
3. Install the four M8 bolts that attach the oil pump to the balance support and torque to 25 lb·ft (34 N·m).
4. To aid balancer timing, leave the oil pump gear holding tool J 39816 in place until the balance assembly is installed in the engine.
5. Install new o-ring seals on both ends of the oil pump outlet tube and lubricate them with clean engine oil.
6. Loosely assemble the left and right side oil inlet tube brackets to the inlet tube using the M10 nuts and bolts.
7. Install one end of the oil pump outlet tube into the inlet tee, the other into the pump body.
8. Install the inlet tee and attach the relief valve using two M8 bolts and torque to 25 lb·ft (34 N·m).
9. Install the regulator valve using two M8 bolts and torque to 25 lb·ft (34 N·m).
10. Install the two M10 bolts that attach the left and right side oil inlet tube brackets to the support and torque to 35 lb·ft (47 N·m).

11. Tighten the M10 bolts and nuts that fasten the tube bracket assembly to the inlet tube.
12. Attach the balancer assembly to the transmission jack stand J 39814.
13. Use guide studs in opposite center holes to properly align the balance shaft support.
14. Before attaching the balance shaft assembly to the block, make sure the timing marks are aligned correctly. See Figure 3–12.

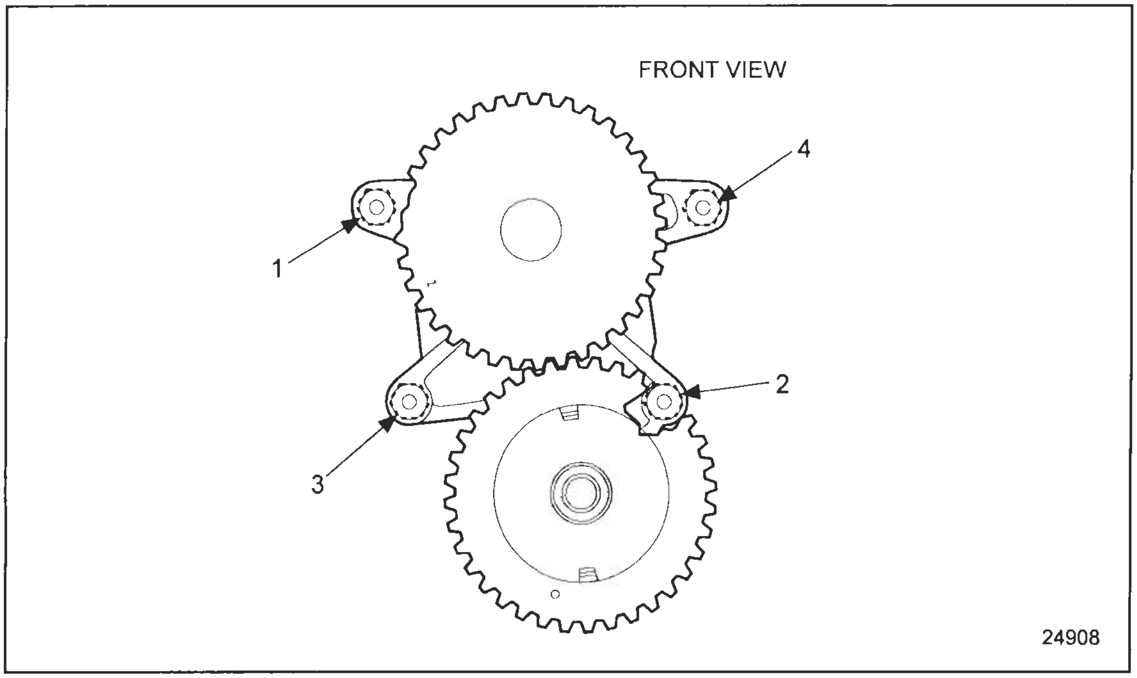


Figure 3–12 Oil Pump Torque Sequence

15. Raise the balance shaft assembly to the cylinder block and attach it using the nine M12 bolts and torque to 85 lb·ft (115 N·m).
16. Remove guide studs and install remaining two M12 bolts and torque to 85 lb·ft (115 N·m).
17. Remove the oil pump gear holding tool J 39816 from the balance shafts.
18. Install the oil pan. Refer to section 3.9.3

3.3 OIL PRESSURE REGULATOR VALVE

An oil pressure regulator valve maintains stable lubricating oil pressure within the engine, regardless of the oil temperature. Oil leaving the pump under pressure passes into the pressure relief valve. The valve is installed into a vertically drilled passage in the balance assembly. See Figure 3–13.

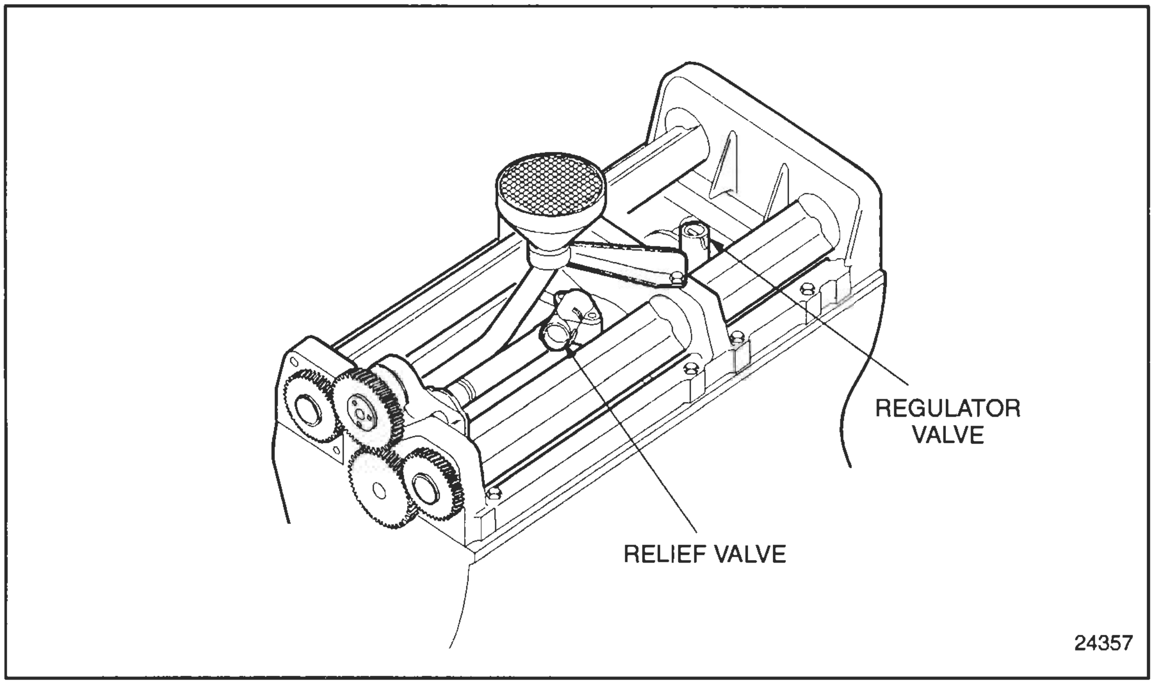
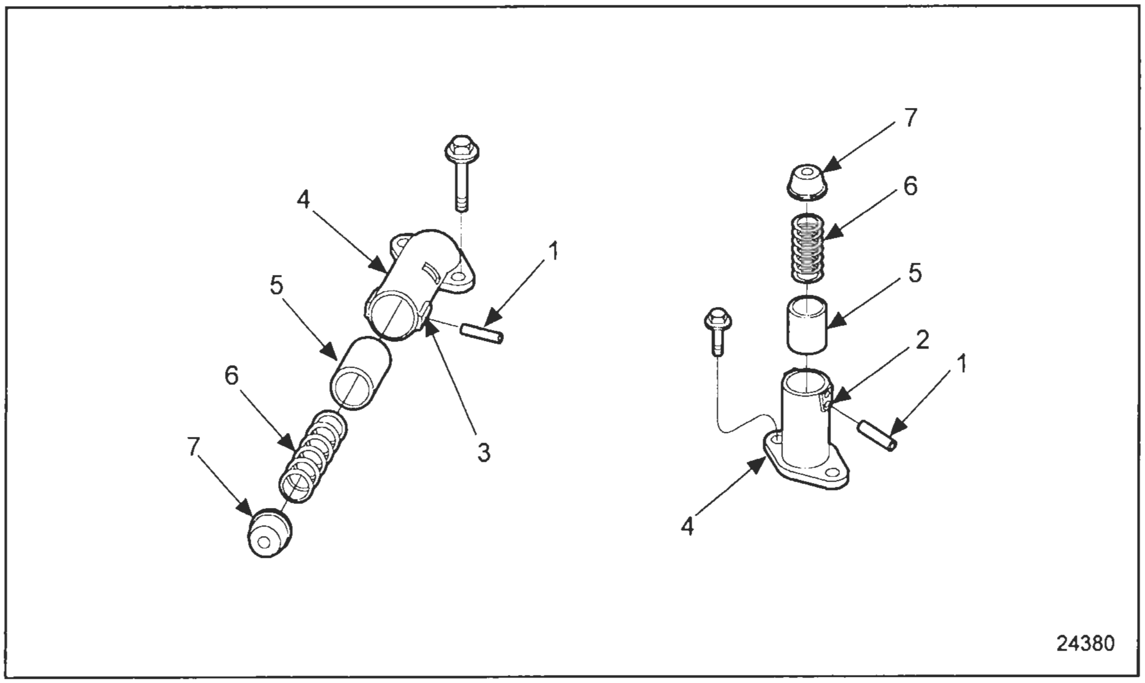


Figure 3–13 Oil Pressure Regulator and Relief Valve Mounting

The oil pressure regulator consists of a valve body, a hollow, piston–type valve, a spring, a spring seat and a pin to retain the valve assembly within the valve body. See Figure 3–14.



1. Pin
2. Pressure Regulator Pin Location
3. Pressure Relief Valve Pin Location
4. Valve Body
5. Valve
6. Spring
7. Spring Seat

Figure 3–14 Oil Pressure Regulator and Relief Valve Details

The valve is held on its seat by the spring, which is compressed by the pin in back of the spring seat. The entire assembly is bolted to the balance support and sealed against leaks by a gasket between the block and valve body. When conditions are such that the oil pressure at the valve exceeds 310 kPa (45 lb/in.), the valve begins to be forced from its seat and oil from the engine gallery is bypassed to the engine oil pan. Thus, stable lubricating oil pressure is maintained at all times.

NOTE:
Whenever the lubricating oil pump is removed for inspection, remove the regulator valve and spring and thoroughly clean and inspect them.

3.3.1 Repair or Replacement of Oil Pressure Regulator Valve

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3–15.

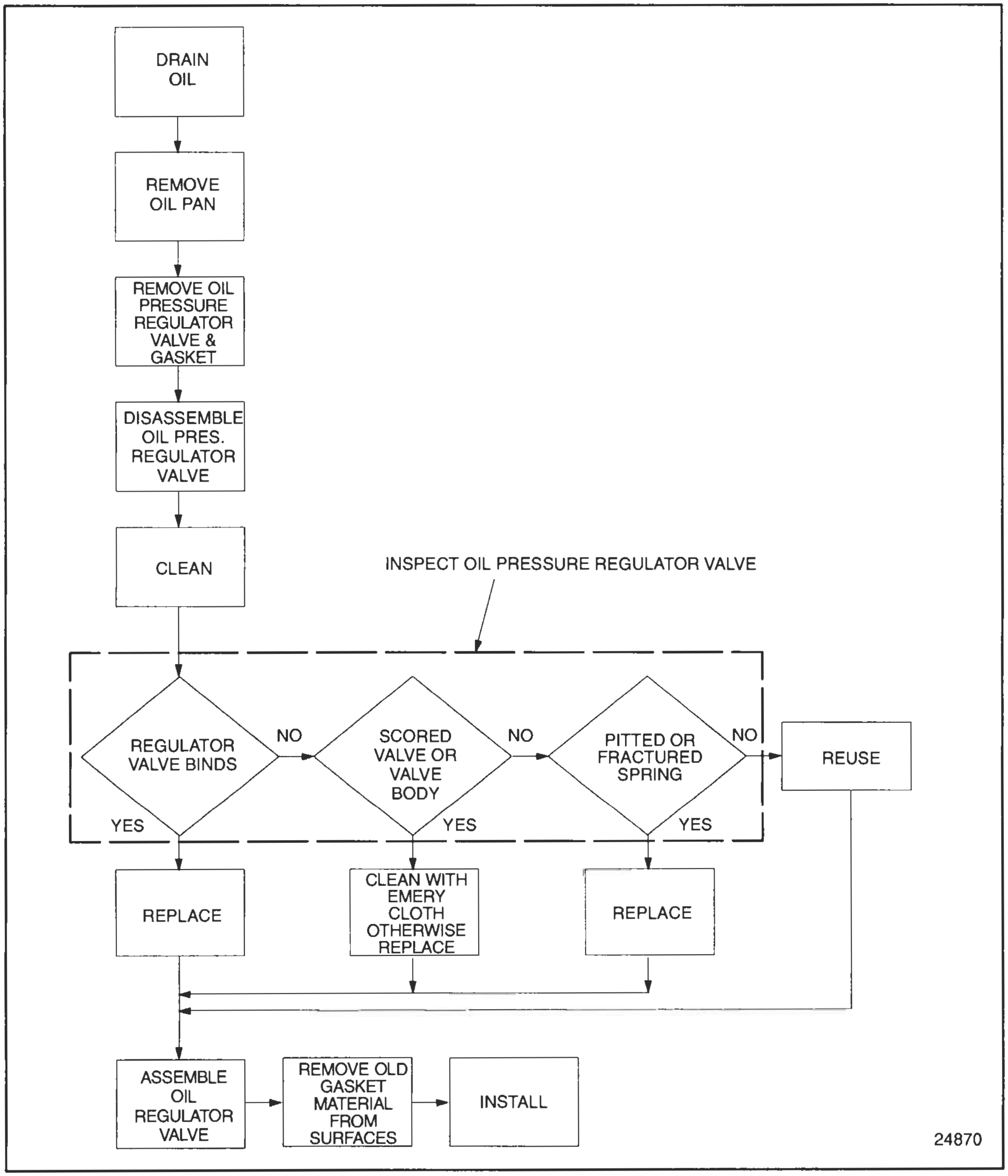


Figure 3–15 Flowchart for Repair or Replacement of Oil Pressure Regulator Valve

3.3.2 Draining and Removal of Oil Pressure Regulator Valve

Precleaning is not necessary.

Remove the oil pressure regulator valve as follows:

1. Drain the lubricating oil and remove the oil pan. Refer to section 3.9.2.
2. Remove the two regulator-to-balance support attaching bolts and washers.
3. Tap the regulator body lightly to loosen it from the balance support.
4. Remove the oil pressure regulator valve.

3.3.3 Disassembly of Oil Pressure Regulator Valve

Disassemble the oil pressure regulator valve as follows:

1. Clamp the regulator in the soft jaws of a bench vise.

CAUTION:

Use care when removing the retaining pin, as the internal parts are under spring pressure and may cause personal injury.

2. Remove the spring seat retaining pin from the regulator body.
3. Remove the spring seat, spring and valve from the regulator body.

3.3.3.1 Inspection of Oil Pressure Regulator Valve

Inspect the oil pressure regulator valve as follows:

1. Clean all of the oil pressure regulator valve components in fuel oil.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

2. Dry the components with compressed air.
3. Inspect the oil pressure regulator valve for movement.
   [a] Check to see if the oil pressure regulator valve moves freely in the valve body.
   [b] If oil pressure regulator valve binds, replace it with a new part.
4. Inspect the components for wear or damage.
   [a] Check to see if valve or the valve body are scored.
   [b] If the valve or valve body parts cannot be cleaned up with a fine emery cloth, replace with new parts.
5. Inspect spring for following:
   [a] Check for pitting or fractures.
   [b] If spring is damaged, replace it with a new part.

3.3.4 Assembly of Oil Pressure Regulator Valve

Assemble the regulator valve as follows:

1. Apply clean engine oil to the outer face of the valve.
2. Slide it into the regulator body, closed end first. See Figure 3–14.
3. Insert the spring in the valve and install the spring seat.
4. While compressing the spring, install the retaining pin behind the spring seat.
5. Press the pin flush to 0.254 mm (.010 in.) below the surface of the valve body.

NOTE:
The valve body has two retaining pin holes. Install the pin in the outermost hole for the regulator valve. The retaining pin must be positioned correctly so the proper valve opening pressure will be obtained. Although the same casting is used for both the pressure regulator and relief valves, the regulator valve has a slightly larger opening machined into the side. See Figure 3–16.

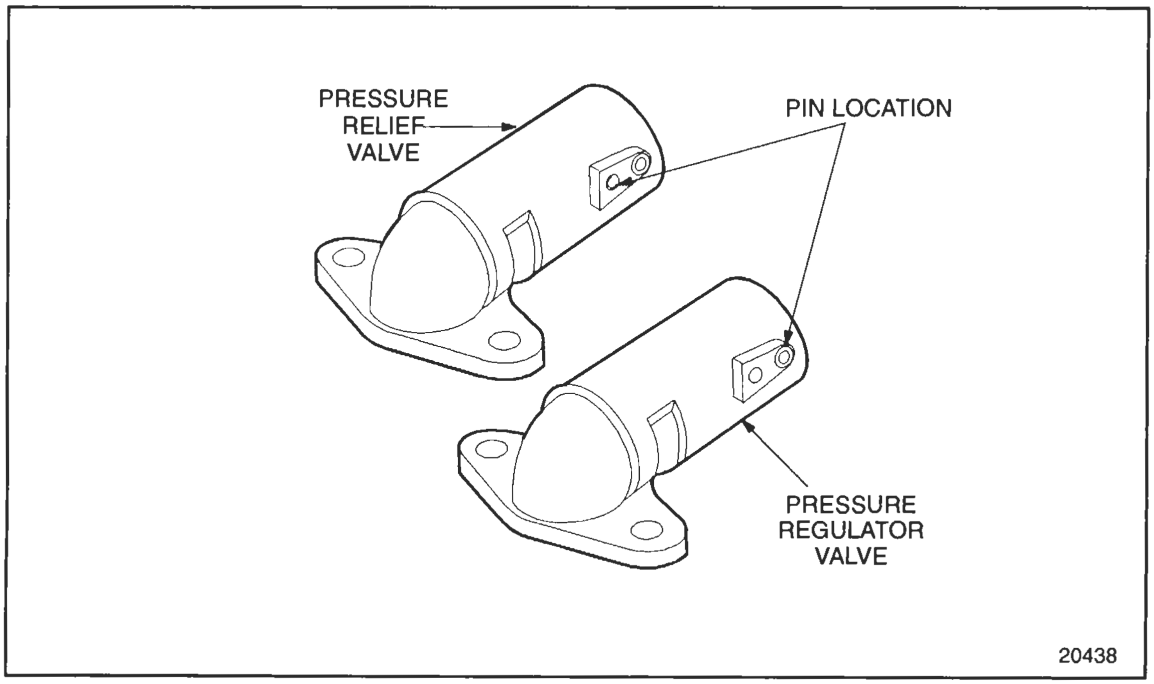


Figure 3–16 Comparison of Pressure Regulator and Relief Valve Assemblies

3.3.5 Installation of Oil Pressure Regulator Valve

Install the oil pressure regulator valve as follows:

1. Remove all traces of old gasket material from the mating surfaces of the regulator body and the balance support.

NOTE:
Detroit Diesel has determined that, when the oil pressure regulator is properly fastened to the cylinder block, a gasket between the block oil gallery and the valve body is not required. Due to the flatness tolerances of the valve face and the block mounting surfaces, the seepage of lubricating oil around the valve body at this joint is minimal and has no significant effect on oil system pressure requirements. For this reason, the regulator valve–to–block gasket has been eliminated from all Series 50 engines.

2. Secure the regulator assembly to the balance support with two bolts. Tighten the bolts to 30–38 N·m (22–28 lb·ft) torque.
3. Refer to section 11.1.2 for verification of proper oil pressure regulator installation.

3.4 OIL PRESSURE RELIEF VALVE

Oil leaving the pump under pressure passes into the pressure relief valve body. The spring–loaded valve opens when the pressure exceeds 690 kPa (100 lb/in.^{2}) and directs the excess oil to the oil pan. The pressure relief valve is mounted on the oil outlet adaptor in the balance support assembly.

The pressure relief valve consists of a valve body, a hollow piston–type valve, spring, spring seat and pin to retain the valve assembly within the valve body.

The relief valve assembly used is composed of the same parts as the regulator valve assembly with the exception of the body. See Figure 3–14.

NOTE:
The valve body has two retaining pin holes. Install the pin in the outermost hole for the regulator valve. The retaining pin must be positioned correctly so the proper valve opening pressure will be obtained. Although the same casting is used for both the pressure regulator and relief valves, the regulator valve has a slightly larger opening machined into the side. See Figure 3–16.

The spring in the relief valve assembly is the same as used in the oil pressure regulator assembly.

3.4.1 Repair or Replacement of Oil Pressure Relief Valve

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-17.

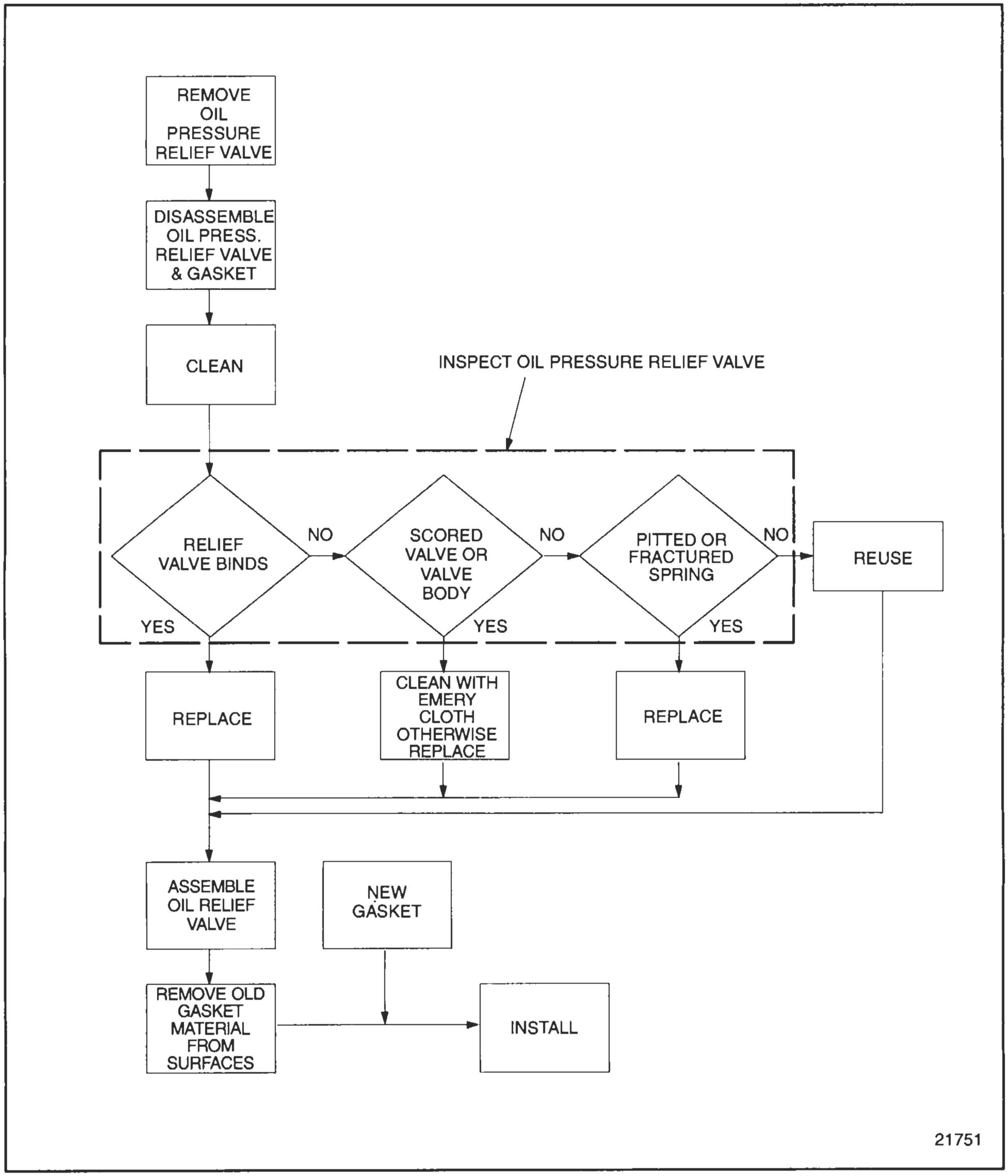


Figure 3-17 Flowchart for Repair or Replacement of Oil Pressure Relief Valve

3.4.2 Cleaning and Removal of Oil Pressure Relief Valve

Precleaning is not necessary.

Remove the oil pressure relief valve as follows:

1. Drain the lubricating oil and remove the oil pan. Refer to section 3.9.2.
2. Remove the two bolts and washers securing the relief valve to the balance support.
3. Tap the oil pressure relief valve body lightly to loosen it from the balance support.
4. Remove the oil pressure relief valve and gasket.

3.4.3 Disassembly of Oil Pressure Relief Valve

Disassemble the oil pressure relief valve as follows:

1. Clamp the oil pressure relief valve in the soft jaws of a bench vise.

CAUTION:

Use care when removing the retaining pin, as the internal parts are under spring pressure and may cause personal injury.

2. Remove the spring seat retaining pin from the oil pressure relief valve body.
3. Remove the spring seat, spring and valve from the oil pressure relief valve body.

3.4.3.1 Inspection of Oil Pressure Relief Valve

Clean the oil pressure relief valve prior to inspection as follows:

1. Clean all of the oil pressure relief valve components in fuel oil.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

2. Dry the components with compressed air.

Inspect the oil pressure relief valve as follows:

1. Inspect the oil pressure relief valve for movement.
   [a] Check to see if the oil pressure relief valve moves freely in the valve body.
   [b] If relief valve binds, replace it with a new part.
2. Inspect the components for wear or damage.
   [a] Check to see if valve or the valve body are scored.
   [b] If the valve and valve body parts cannot be cleaned up with a fine emery cloth, replace with new parts.
3. Inspect spring for following:
   [a] Check for pitting or fractures.
   [b] If spring is damaged, replace it with a new part.

3.4.4 Assembly of Oil Pressure Relief Valve

Assemble the relief valve as follows:

1. Apply clean engine oil to the outer face of the valve.
2. Slide it into the oil pressure relief body, closed end first. See Figure 3-14.
3. Insert the spring in the valve and install the spring seat.

NOTICE:
The retaining pin must be positioned correctly so the proper valve opening pressure will be obtained. Although the same casting is used for both the pressure regulator and relief valves, the regulator valve has a slightly larger opening machined into the side. See Figure 3–16.

4. While compressing the spring, install the retaining pin behind the spring seat.
5. Press the pin flush to 0.254 mm (.010 in.) below the surface of the valve body.

3.4.5 Installation of Oil Pressure Relief Valve

Install the oil pressure relief valve as follows:

1. Remove all traces of old gasket material from the mating surfaces of the oil pressure relief valve body and the balance support.
2. Secure the oil pressure relief valve assembly to the balance support with two bolts. Tighten the bolts to 30–38 N·m (22–28 lb·ft) torque.
3. Refer to section 11.1.2 for verification of proper oil pressure relief valve installation.

3.5 OIL FILTER

Two full flow type lubricating oil filters are used on the Series 50 engine. The oil filters are mounted in a downward position. The filters are of the throw away, spin-on type. See Figure 3-18.

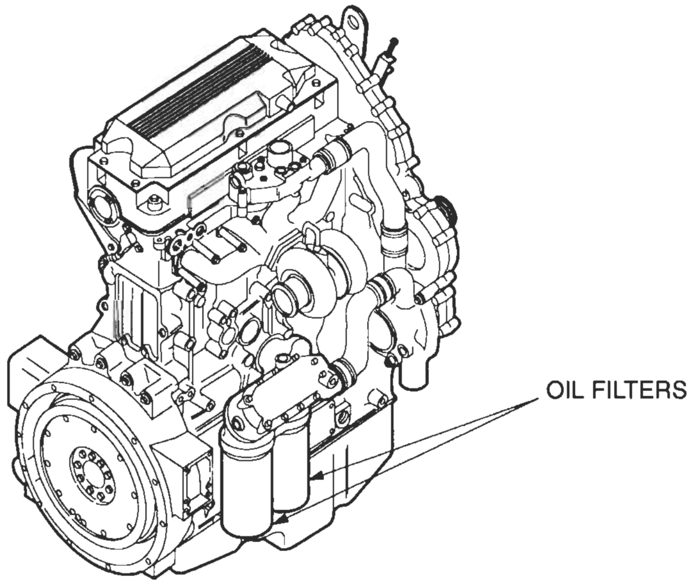


Figure 3-18 Spin-on Oil Filters

Oil supplied by the engine oil pump passes through the full flow filters before reaching the various moving parts of the engine. The oil is forced by pump pressure through a passage in the filter adaptor and into the elements. Impurities are filtered out as the oil passes through the elements and out through another passage in the filter adaptor.

3.5.1 Repair or Replacement of Oil Filters

Repair is not possible. Replace using the following procedure:

1. Remove oil filter. Refer to section 3.5.2.
2. Install new oil filter. Refer to section 3.5.3.

3.5.2 Cleaning and Removal of Oil Filter

Precleaning is not necessary.

Remove oil filter as follows:

1. Remove the oil filter using oil filter wrench J 29917 and discard the used oil filters.
2. Examine the sealing surface of the filter to ensure that the seal ring is attached to the filter. If not, remove it from the adaptor.

Prior to installation, clean the filter adaptor with a clean, lint-free cloth.

3.5.3 Installation of Oil Filter

Install oil filter as follows:

1. Lightly coat the new oil filter seal with clean engine oil.
2. Start a new filter on the adaptor, and tighten it by hand until the seal touches the adaptor filter head.

NOTICE:
Mechanical tightening is not necessary and will distort or crack the adaptor.

3. Tighten the filter an additional 2/3 turn after contact.
4. Refer to section 11.1.2 or refer to section 13.5.10 for verification of proper oil filter installation.

3.6 OIL FILTER ADAPTOR

Oil filter adaptor is located on the right side of the engine and is joined to the oil cooler.

A bypass valve in the filter adaptor opens at approximately 124–145 kPa (18–21 lb/in.^{2}) pressure differential, and will bypass the oil filters should the full flow filters become plugged.

3.6.1 Repair or Replacement of Oil Filter Adaptor

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3-19.

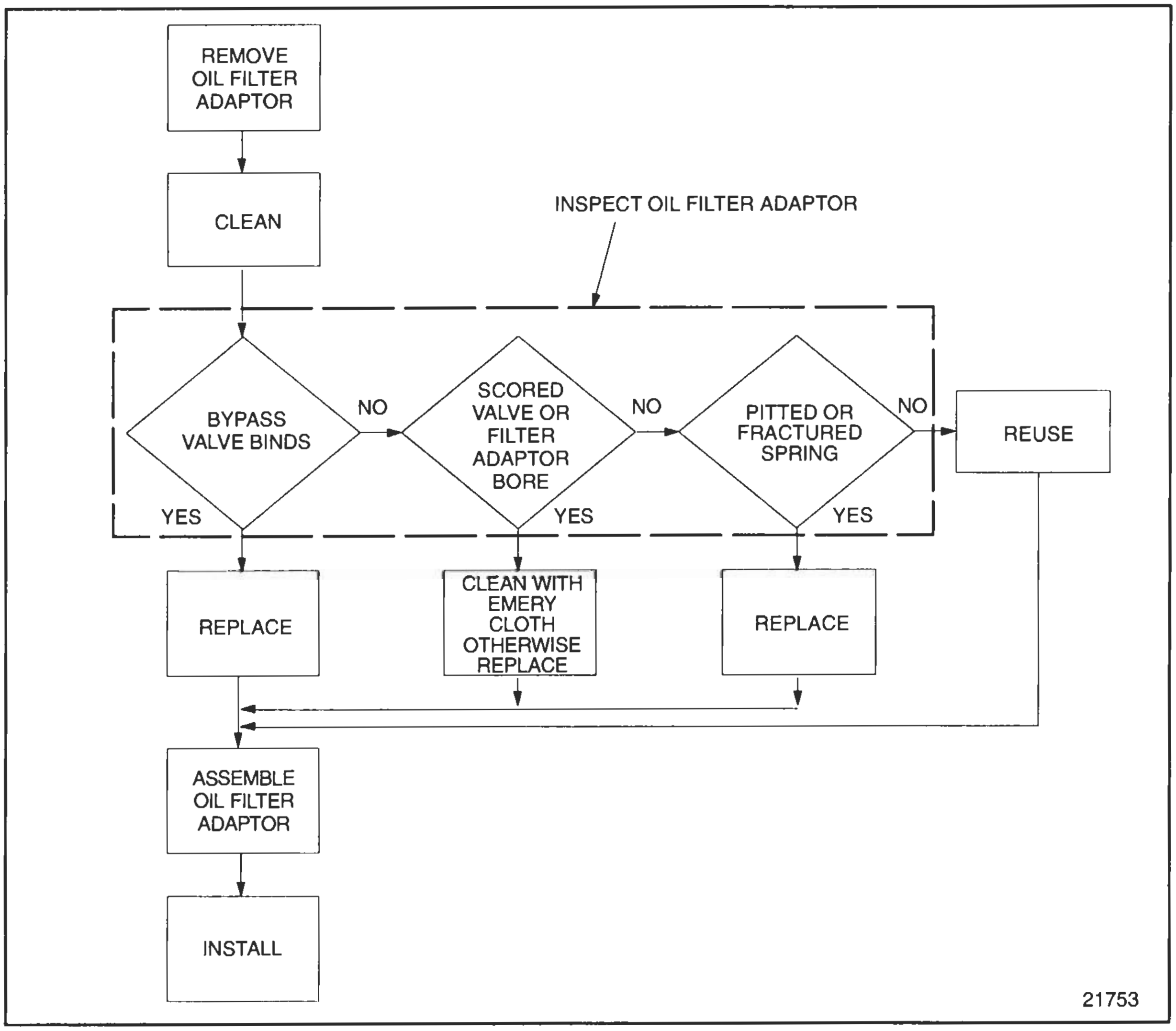


Figure 3-19 Flowchart for Repair or Replacement of Oil Filter Adaptor

3.6.2 Cleaning and Removal of Oil Filter Adaptor

Precleaning is not necessary.

Remove the oil filter adaptor as follows:

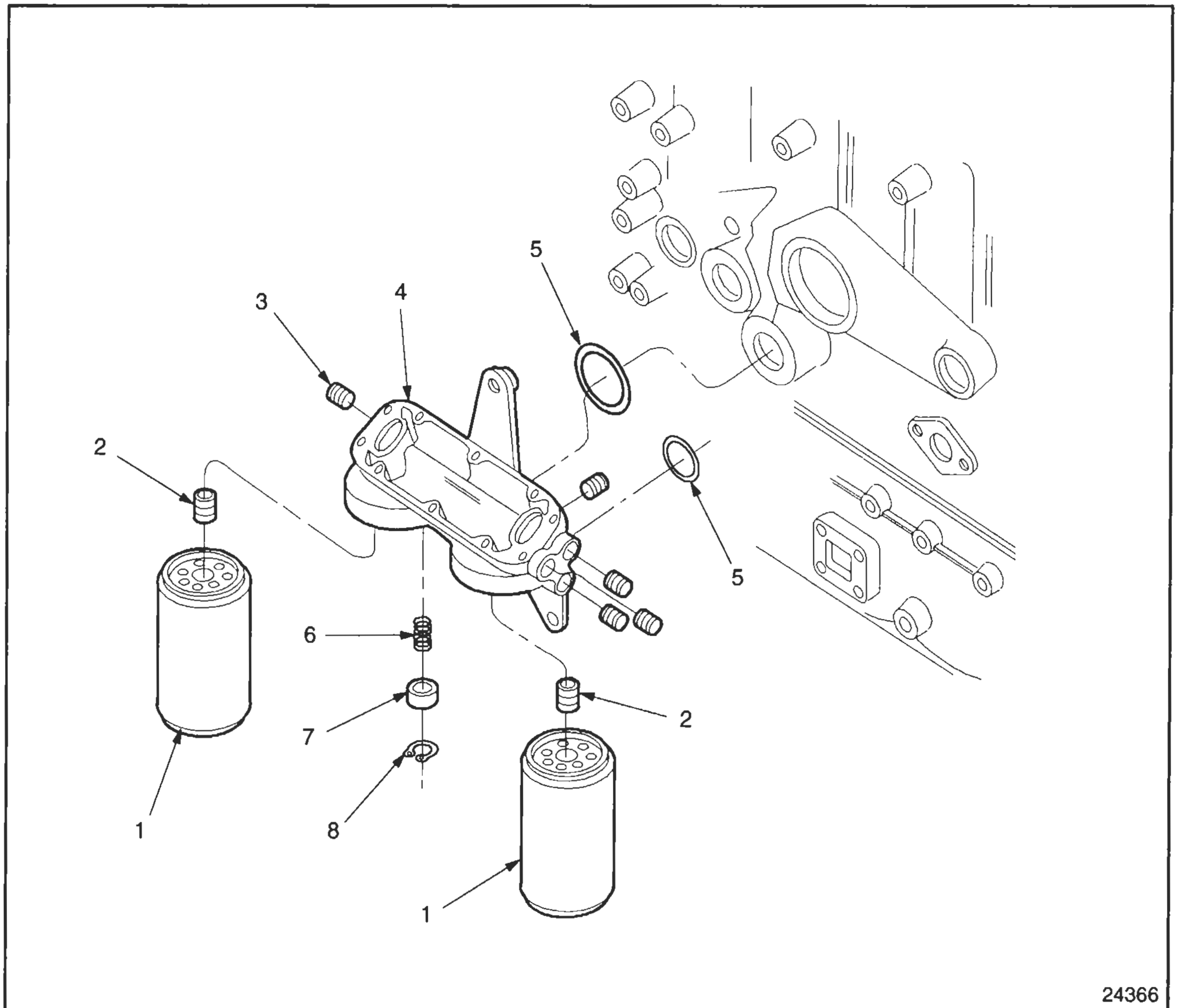
1. Remove the four bolts that connect the oil filter adaptor to the block.

CAUTION:

Use care when removing the snap ring, as the internal parts are under spring pressure and may cause personal injury.

2. Remove the snap ring.

3. Withdraw the spring and bypass valve. See Figure 3-20.



1. Oil Filter, Full Flow
2. Insert, Full Flow Filter–to–Adaptor
3. Pipe Plugs (5)
4. Oil Filter Adaptor
5. O–ring, Adaptor–to–Block
6. Spring, Bypass
7. Valve, Bypass
8. Snap Ring

Figure 3–20 Oil Filter Adaptor, Bypass Valve and Related Parts

4. Remove the pipe plugs.

3.6.2.1 Inspection of Oil Filter Adaptor

Inspect the oil filter adaptor as follows:

1. Clean all of the oil filter adaptor components in fuel oil.

> **CAUTION:**
>
> **To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.**

2. Dry the parts with compressed air.
3. Inspect the bypass valve for movement.
   [a] Check to see if the bypass valve moves freely in the adaptor.
   [b] If the bypass valve binds, replace it with a new part.
4. Inspect the components for wear or damage.
   [a] Check to see if the valve or the filter adaptor bore are scored.
   [b] If the valve and the filter adaptor bore parts cannot be cleaned up with a fine emery cloth, replace with new parts.
5. Inspect the spring for damage.
   [a] Check for pitting or fractures.
   [b] If spring is damage, replace it with a new part.

3.6.3 Assembly of Oil Filter Adaptor

Assemble the oil filter adaptor as follows:

1. Install the bypass valve.
2. Using tool J 23432, install snap rings.
3. Replace the O-rings.
4. Coat new O-rings with petroleum jelly.
5. Install the O-rings in the recesses in the oil filter adaptor.

3.6.4 Installation of Oil Filter Adaptor

Install oil filter adaptor as follows:

1. Install the pipe plugs.
   [a] Apply a sealant such as, Loctite 620, (or equivalent) to the threads the will engage the adaptor.
   [b] Wipe off any sealant remaining exposed threads.
   [c] Tighten all pipe plugs to 95–119 lb·ft (129–161 N·m) torque.
2. Install the oil filter adaptor to the cylinder block. Tighten the mounting bolts to 30–38 N·m (22–28 lb·ft) torque.
3. Refer to section 11.1.2 for verification of proper oil filter adaptor installation.

3.7 OIL COOLER

In order to perform its functions satisfactorily, the lubricating oil must be kept within the proper temperature limits. If the oil is too cold, it will not flow freely. If the oil is too hot, it cannot support the bearing loads, and it cannot carry away enough heat. High oil temperature may cause, oil pressure to drop below acceptable limits and oil consumption to become excessive.

While performing its lubricating and cooling functions, the oil absorbs a considerable amount of heat, and this heat must be dissipated by an oil cooler.

Series 50 engines use a 9-plate oil coolers.

The lubricating oil cooler is mounted on the right side of the cylinder block near the water pump. See Figure 3-21.

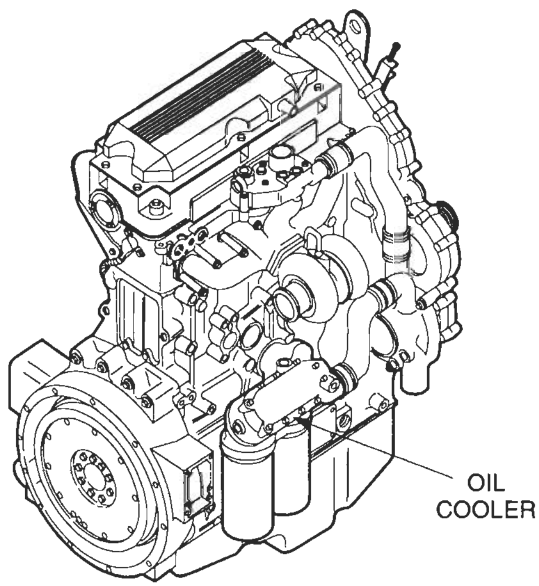
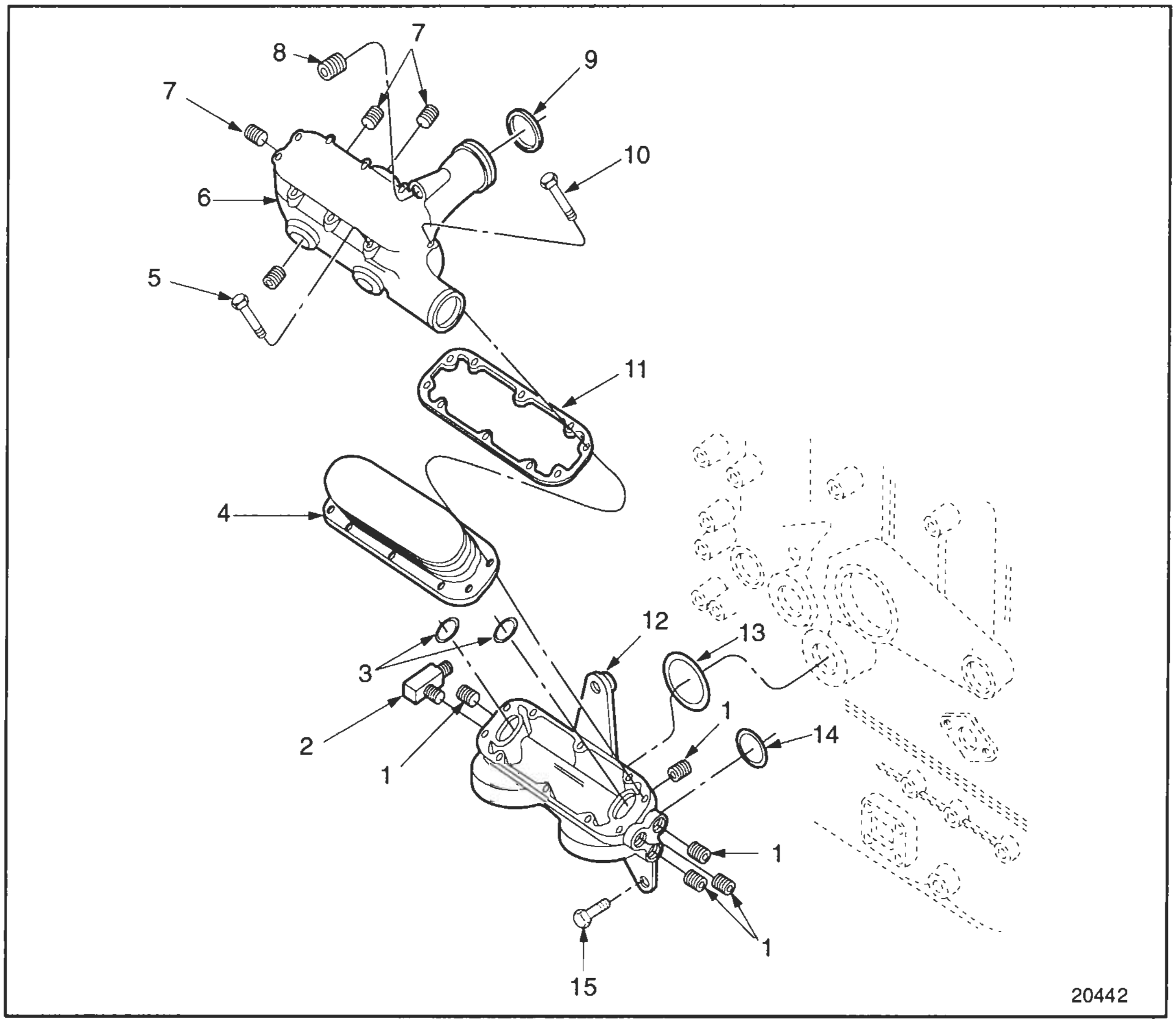


Figure 3–21 Lubricating Oil Cooler

To assure continued engine lubrication if the oil cooler becomes plugged, a bypass passage, located at the oil cooler inlet, bypasses oil around the cooler directly to the oil gallery in the cylinder block.

Cooling water is circulated through the oil cooler housing completely surrounding the oil cooler core. Therefore, whenever an oil cooler is assembled, care must be taken to have the proper gaskets in place and the retaining bolts tight to assure good sealing.

The oil cooler housing coolant outlet uses one large rubber O–ring seated in a groove in the outlet neck. See Figure 3–22.



1. Pipe Plugs (5)
2. Fitting
3. O–rings (2)
4. Oil Cooler
5. Bolt, Oil Cooler Housing–to–Adaptor (3)
6. Oil Cooler Housing
7. Pipe Plugs (4)
8. Pipe Plug
9. O–ring
10. Bolt, Oil Cooler Housing–to–Adaptor (7)
11. Gasket, Oil Cooler–to–Housing
12. Oil Filter Adaptor
13. O–ring
14. O–ring
15. Bolt, Oil Filter Adaptor–to–Block (5)

Figure 3–22 Oil Cooler Housing and Related Parts

Two small O–rings are positioned in oil filter adaptor counterbores to seal the lubricating oil passages between the oil filter adaptor and the cooler core.

The oil cooler housing is attached to the oil filter adaptor. The flow of oil is from the oil pump, through a vertical passage in the cylinder block, through the full flow oil filters and then through the oil cooler core and the cylinder block main oil galleries.

3.7.1 Repair or Replacement of Oil Cooler

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3–23.

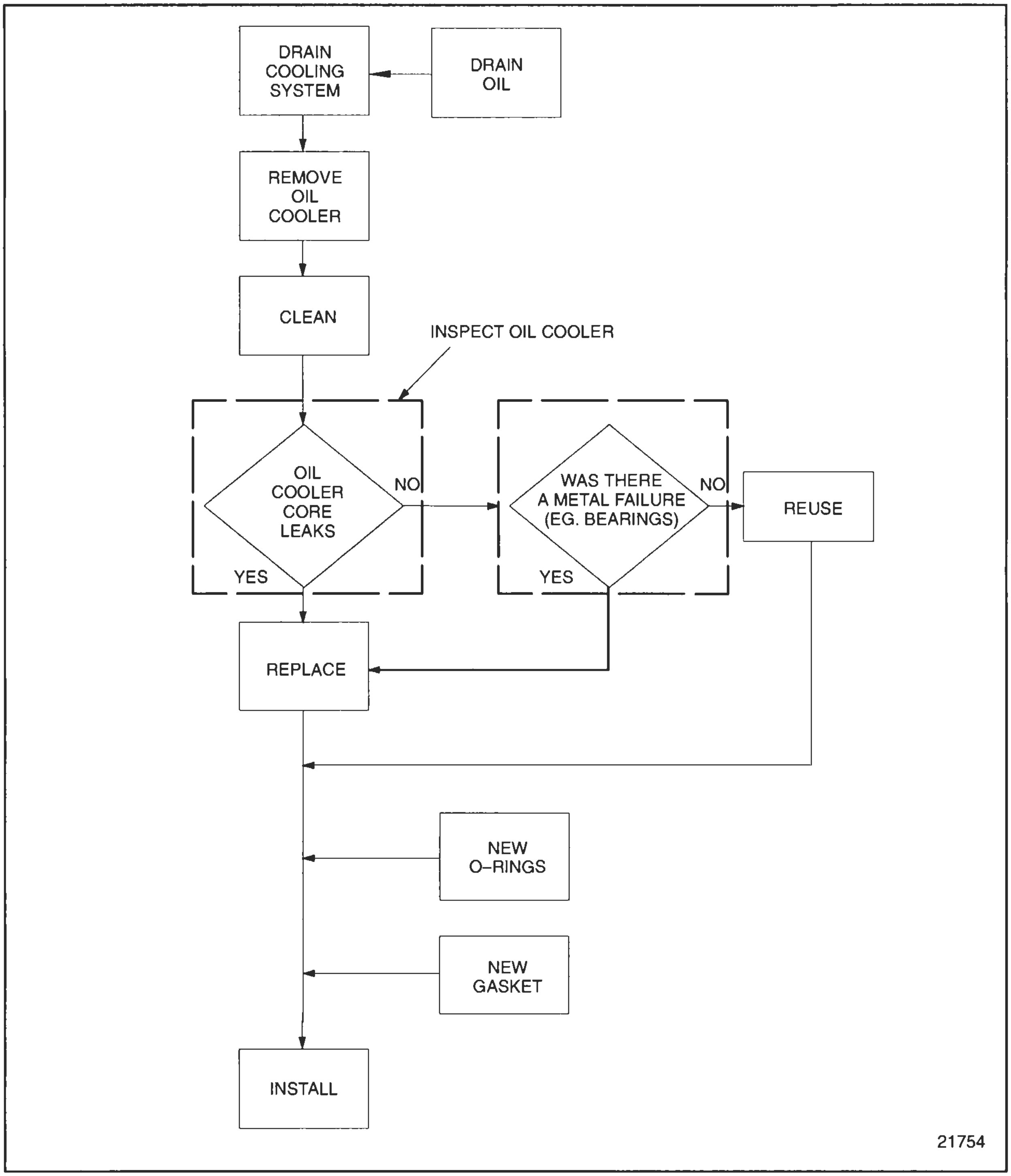


Figure 3–23 Flowchart for Repair or Replacement of Oil Cooler

3.7.2 Cleaning and Removal of Oil Cooler

Precleaning is not necessary.

Remove the oil cooler core and housing as follows:

1. Drain the cooling system by opening the drain cocks at the right rear of the cylinder block, and in the bottom of the water pump housing.
2. Disconnect the hose from the water pump at the lower neck of the oil cooler housing.
3. Matchmark the oil cooler core and housing to ensure correct reinstallation.
4. Remove the bolts which attach the oil cooler housing and core to the oil filter adaptor.
5. Place a pry bar between the oil cooler housing and cylinder block, just below the upper neck. Gently pry the oil cooler housing from the cylinder block and the oil filter adaptor.
6. Use a gasket scraper or chisel and a fiber mallet or plastic hammer to separate the oil cooler core and housing.
7. Remove all traces of gasket material from the oil cooler and housing.

Clean the oil cooler core prior to inspection as follows:

1. Remove the core from the oil cooler.

CAUTION:

To prevent injury, (when toxic chemicals are used for cleaning), the following operation should be done in an open or in a well ventilated room.

NOTICE:

Do not attempt to clean an oil cooler when an engine failure releases metal particles from worn or broken parts are released into the lubricating oil. The oil cooler core must be replaced. Otherwise, severe engine damage may result.

2. Circulate a solution of 1,1,1–trichloroethylene through the core passages with a force pump to remove the carbon and sludge.
3. Clean the core before the sludge hardens.
4. If the oil passages are badly clogged, circulate an Oakite c solution through the core and flush thoroughly with clean, h

Clean the coolant side of the core:

CAUTION:

Protect your eyes and avoid breathing the fumes or direct contact of the acid with your skin.

1. Mix the following solutions: Add one–half pound of oxalic acid to each two and one–half gallons of solution composed of one third muriatic acid and two–thirds water.
2. Immerse the core in the solution.
3. Watch the process carefully. When bubbling stops (this usually takes from 30 to 60 seconds), remove the core from the cleaning solution.
4. Thoroughly flush it with clean, hot water.
5. Dip the core in light oil.

3.7.2.1 Inspection of Oil Cooler

Inspect oil cooler as follows:

1. Make a suitable plate and attach it to the flanged side of the cooler core. Use a gasket made from rubber to insure a tight seal.
2. Drill and tap the plate prior to mounting to permit an air hose fitting to be attached at the inlet side of the core. See Figure 3–24.

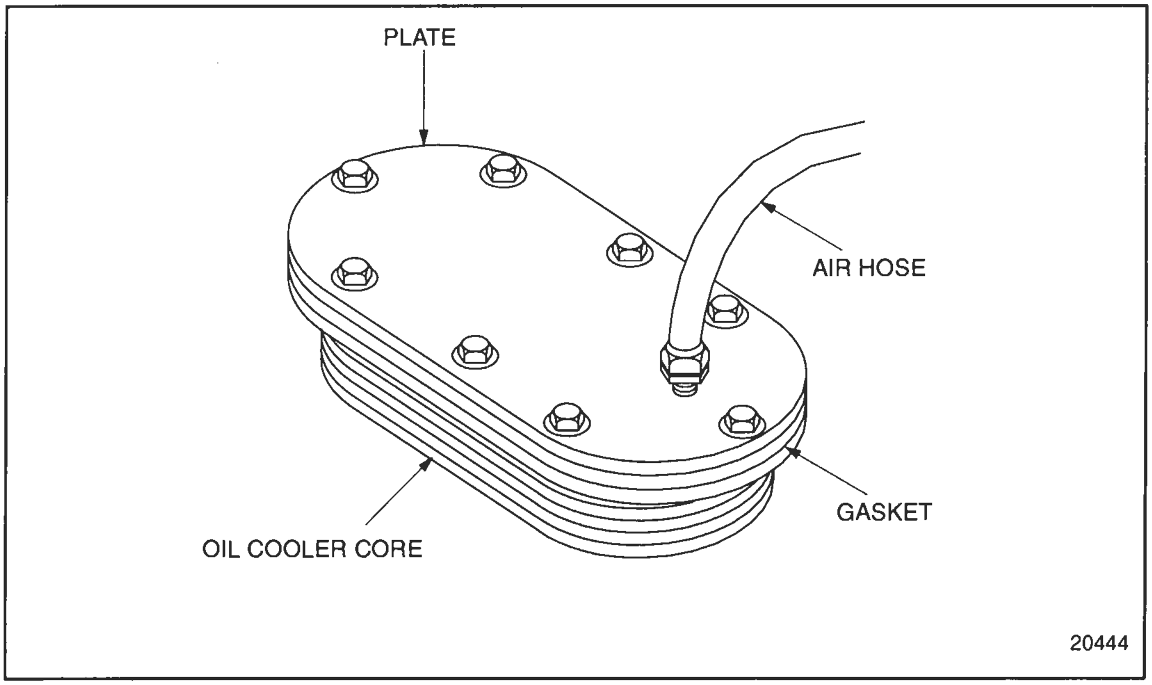


Figure 3–24 Preparing Oil Cooler Core for Pressure Test

> **CAUTION:**
>
> **When making a pressure test be sure that personnel are adequately protected against any stream of pressurized water from a leak or rupture of a fitting, hose or the oil cooler core.**

3. Attach an air hose to the air hose fitting.

4. Regulate air pressure to 517–690 kPa (75–100 lb/in.^{2}) and submerge the oil cooler and plate assembly in a container of water heated to 82°C (180°F).

   [a] Check for leaks as indicated by air bubbles in the water.

NOTICE:
In cases where a leaking oil cooler core has caused contamination of the engine, the engine must be immediately flushed to prevent corrosion to its internal components. Refer to section 13.5.4.

   [b] If leaks are indicated, replace the core.

5. After the pressure check is completed, remove the plate and air hose from the cooler core.

CAUTION:
To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

6. Dry the core with compressed air.

3.7.3 Installation of Oil Cooler

Install the oil cooler core as follows:

1. Lubricate new O–rings with a light coat of petroleum jelly.
2. Install the new O–rings in the counterbores in the oil filter adaptor.
3. Coat the O–ring with ethylene glycol (coolant).
4. Install a new O–ring in the groove on the oil cooler housing outlet neck.
5. Install a new gasket on the face of the core that will contact the housing.

NOTICE:
Use care when installing the oil cooler housing to prevent damaging the outlet neck O–rings on the sharp edges of the opening in the cylinder block. Some cleaning of the block opening is usually needed.

6. Install the core to the housing and install the assembly on the oil filter adaptor.
7. Align the oil cooler housing assembly to the oil filter adaptor. Install the ten oil cooler housing bolts and tighten to 30–38 N·m (22–28 lb·ft) torque using the correct sequence. See Figure 3–25.

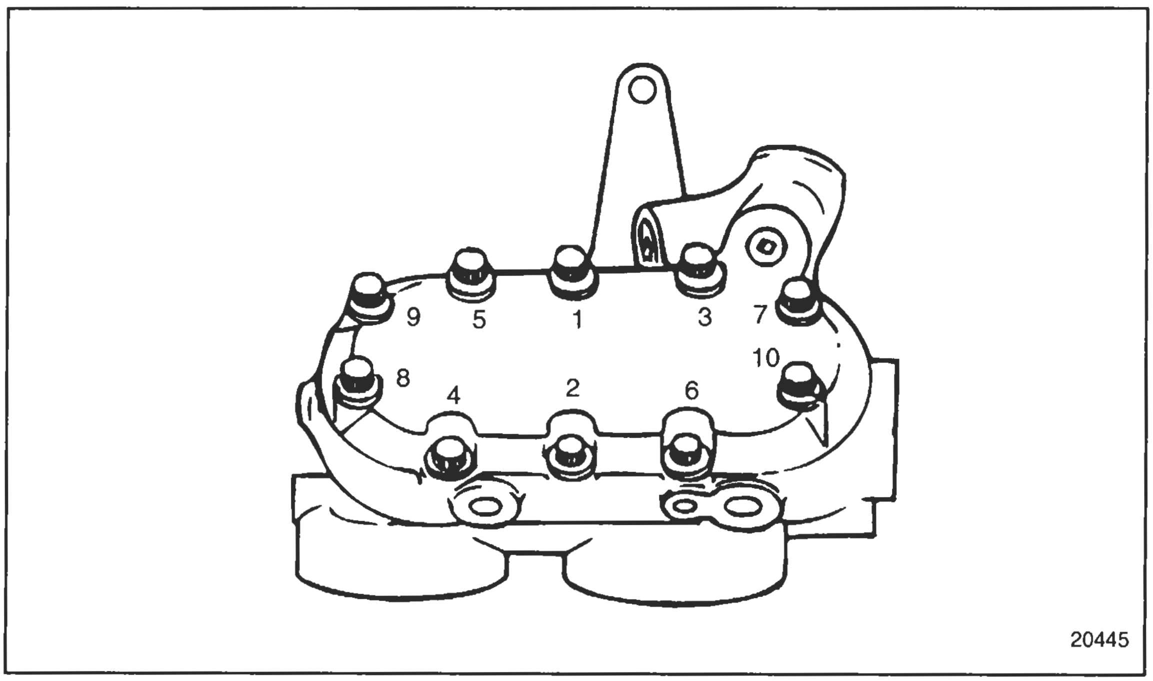


Figure 3–25 Oil Cooler Housing Bolt Torque Sequence

8. Position the hose and clamps in place at the lower neck of the oil cooler housing, making sure the clamps are positioned inside the lip on both the housing and tube. Tighten the clamps.
9. Close the draincocks in the cylinder block and water pump housing. Fill the cooling system. Refer to section 13.5.4.
10. Fill the lubricating system. Refer to section 13.5.1.
11. Refer to section 11.1.1 for verification of proper oil cooler installation.

3.8 OIL LEVEL DIPSTICK ASSEMBLY

A steel ribbon-type oil level dipstick may be used to check the level of oil in the engine oil pan. The dipstick is located in a tube attached by a threaded adaptor to an opening in the oil pan. See Figure 3-26.

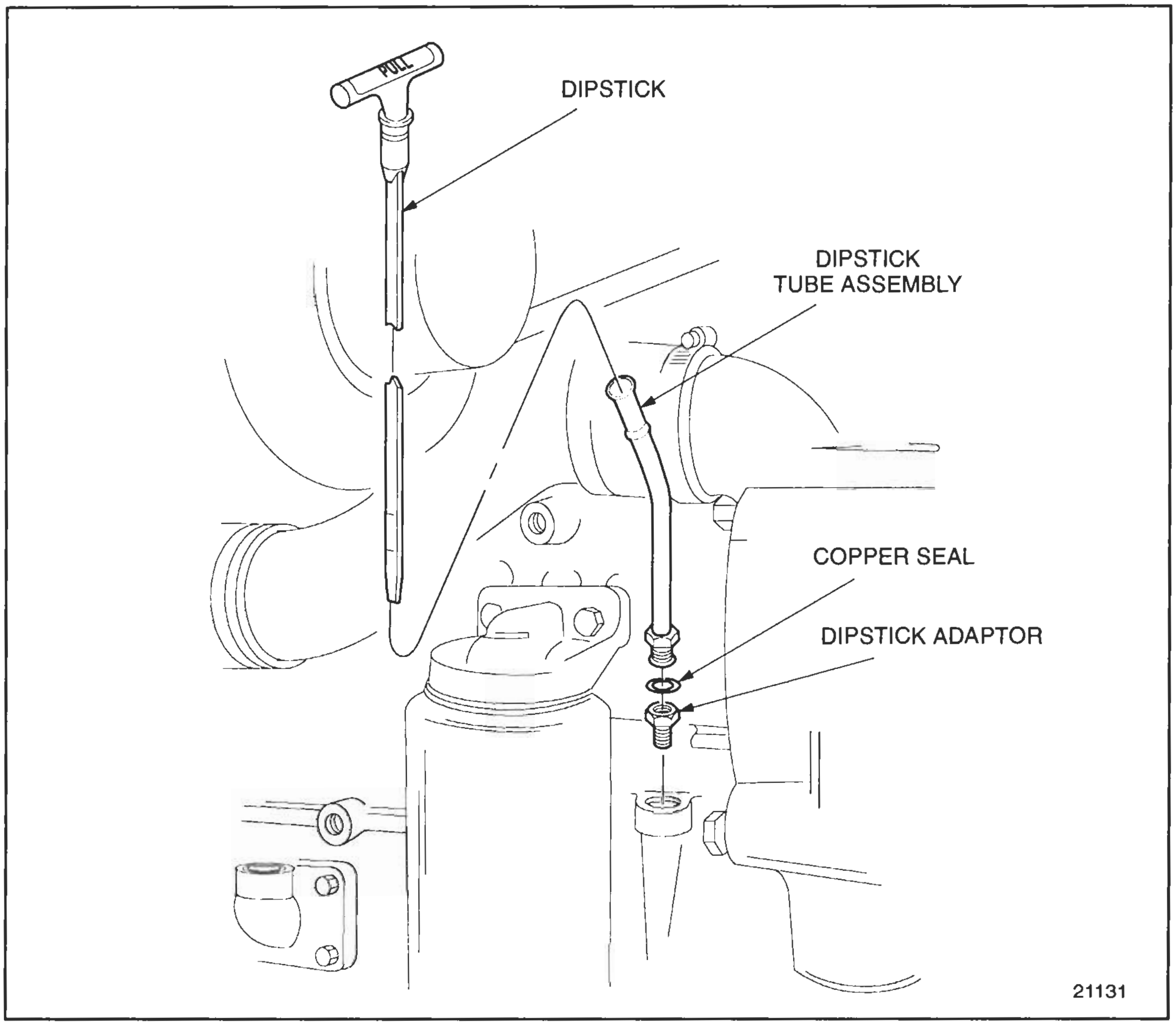


Figure 3-26 Oil Dipstick Mounting

Snap action dipsticks have locking tangs and an O-ring seal in the tee handle. A copper sealing ring between the adaptor and dipstick tube insures a tight seal.

NOTICE:
Maintain the oil level between the full and low marks on the dipstick. Never allow it to drop below the low mark. No advantage is gained by having the oil level above the full mark. Overfilling may cause the oil to be churned by the balance shafts and crankshaft throws causing foaming or aeration of the oil. Operation below the low mark may expose the pump pick–up causing aeration, loss of pressure and engine damage.

Check the oil level after the engine has been stopped for a minimum of ten minutes to permit oil in the various parts of the engine to drain back into the oil pan.

Dipsticks are normally marked for use only when the equipment the engine powers is on a level surface. Improper oil levels can result if the oil level is checked with the equipment on a grade, or if insufficient time is allowed for oil drain back to the sump. For additional information, consult Service Information Bulletin "Oil Level Gauge Calibration Inspection and Fabrication" (SIB 12–50–94).

The current dipstick adaptor has a thicker wall than the former adaptor and requires a copper seal between the adaptor and the nut on the oil gage tube assembly.

3.8.1 Repair or Replacement of Oil Dipstick Assembly

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3–27.

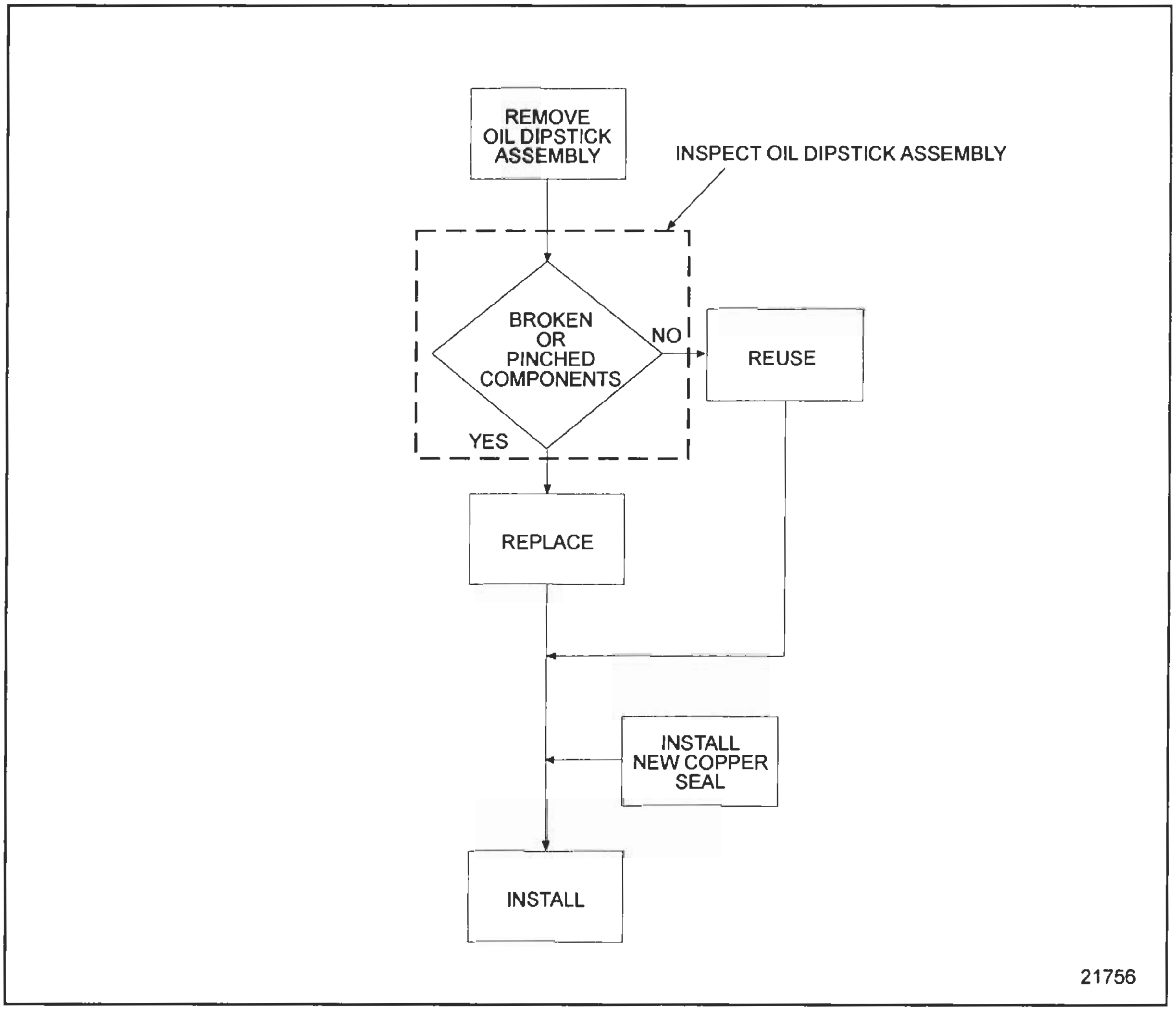


Figure 3–27 Flowchart for Repair or Replacement of Oil Dipstick Assembly

3.8.2 Cleaning and Removal of Oil Dipstick Assembly

Precleaning is not necessary.

Remove oil dipstick assembly as follows:

1. Remove dipstick from dipstick adaptor.
2. Remove oil tube assembly, copper seal, and dipstick adaptor from cylinder block. Discard copper seal.

3.8.2.1 Inspection of Oil Dipstick Assembly

Inspect oil dipstick assembly as follows:

1. Inspect dipstick assembly for any damaged parts.
   [a] Check components for any broken or pinched parts.
   [b] If any components are damaged, replace with new parts.

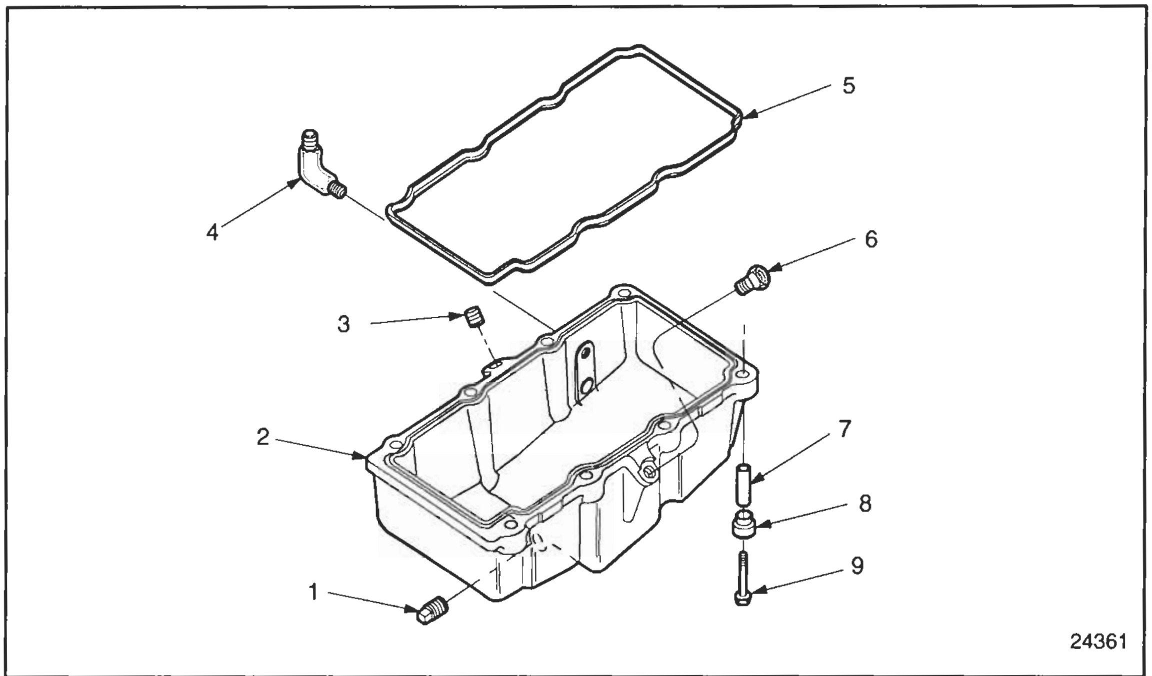
3.8.3 Installation of Oil Dipstick Assembly

Assemble oil dipstick assembly as follows:

1. Install dipstick adaptor onto cylinder block. Tighten to 22 N·m (16 lb·ft) torque.
2. Insert the new copper seal and thread the oil gage tube assembly nut into the adaptor.
3. While holding the adaptor with a wrench, properly align the oil gage tube assembly.
4. Tighten the nut on the tube securely.
5. Install dipstick into tube assembly.

3.9 OIL PAN

The oil pan used on the Series 50 engine is made of aluminum. A one-piece, non-reusable isolator seal is used between the oil pan and block. See Figure 3-28.



1. Drain Plug
2. Oil Pan
3. Pipe Plug
4. Elbow
5. Gasket
6. Adaptor
7. Sleeve
8. Isolator
9. Bolt

Figure 3-28 Typical Oil Pan Assembly

Rubber isolator-washer assemblies and sleeves are used for attaching the oil pan. The metal sleeve spacer is inserted through the isolator and limits the travel of the oil pan bolts to prevent over-tightening and damaging the oil pan and isolator.

When installing a pipe plug, coat the threads with Loctite PT7271 sealant (or equivalent), hold the insert to keep it from turning, and tighten the plug to 45-56 N·m (33-41 lb·ft) torque.

3.9.1 Repair or Replacement of Oil Pan

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3–29.

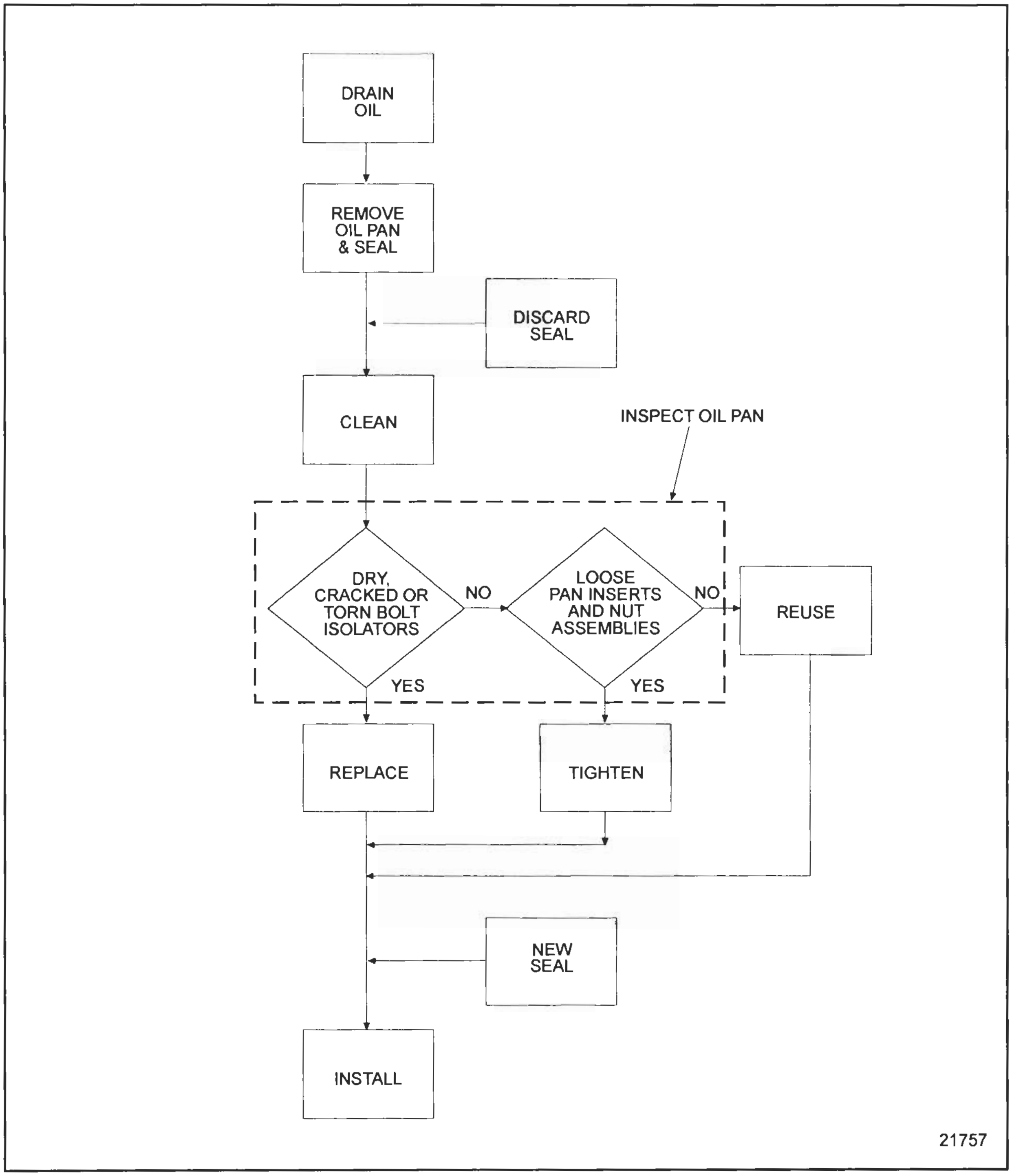


Figure 3–29 Flowchart for Repair or Replacement of Oil Pan

3.9.2 Cleaning and Removal of Oil Pan

Precleaning is not necessary.

NOTICE:
Do not support the engine on the oil pan. Damage to the oil pan or engine could result.

NOTE:
On almost all engine applications it is possible to remove the oil pan without removing the engine.

If the engine is to be removed from the vehicle, the oil pan should be left in place until the engine is removed.

The procedure for removing the oil pan will vary with each installation. However, the following procedures will generally apply.

NOTICE:
When removing a side plug, hold the flats of the insert with a 2 1/8 in. open end or large adjustable wrench to keep it from turning. If the insert is loosened, it may be necessary to remove the oil pan and retighten the nut to prevent a possible oil leak. If required, tighten the nut to 186–199 N·m (137–147 lb·ft) torque.

Remove the oil pan as follows:

1. Remove the drain plug and drain the engine oil. Refer to section 13.5.1.
2. Remove the eight oil pan bolts, washers, isolators and sleeves. Remove the center bolts on each side last.
3. Remove the oil pan, taking care not to damage the oil pump inlet pipe and screen.
4. Remove the oil pan isolator seal and discard.

Clean the oil pan prior to inspection as follows:

NOTICE:

Do not use solvents to clean isolators. Damage to the isolator will result.

1. Clean the oil pan and attaching hardware with clean fuel oil.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

2. Dry with compressed air.
3. Clean the surfaces of the cylinder block, gear case and flywheel housing where they mate with the oil pan.

3.9.2.1 Inspection of Oil Pan

Inspect the oil pan inserts, oil pan, and bolt isolators as follows:

1. Check the bolt isolators for dryness, cracks or tears.
   [a] If isolator is damaged, replace with new part.
2. Check oil pan for major dents, cracks and other damage.
   [a] If oil pan is damaged, replace with new part.

3.9.3 Installation of Oil Pan

Install the oil pan as follows:

1. Insert the raised lip portion of the new isolator seal into the groove in the oil pan.
2. Press down on the isolator seal and insert it completely around the oil pan. Be careful not to stretch or bunch the seal. For best results, install the seal at each corner, then at points half way between the corners. Continue in this manner, halving the distance and seating the seal.
3. Insert a metal sleeve spacer into each isolator.
4. Install the eight oil pan bolts into isolator assemblies.
5. Install the oil pan assembly in position on the cylinder block.
6. Ensure that the isolator seal has not been disturbed. Tighten the eight oil pan bolt assemblies to 25–30 N·m (18–22 lb·ft) torque, using the proper sequence. See Figure 3–30.

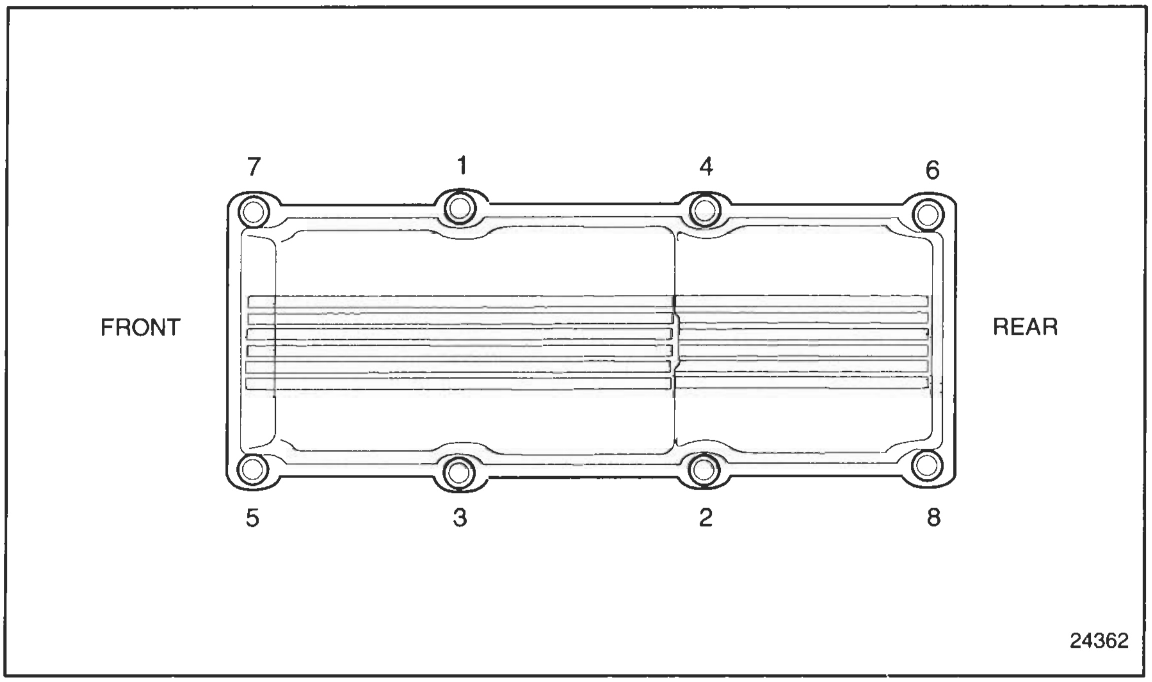


Figure 3–30 Oil Pan Bolt Torque Sequence

7. Install and tighten the 3/4 in.–14 square, magnetic, oil drain plug to 45–56 N·m (33–41 lb·ft) torque.

8. Install and tighten any other plugs that were removed from the oil pan.

NOTE:
When installing a pipe plug, coat the threads with Loctite PT7271 sealant (or equivalent).

9. Add 23 quarts (22 L) of new, clean lube oil (15W–40).

NOTE:
The extra quart of oil (23 verses 22) is added to account for oil in the oil filter adaptor, gallery, etc.

10. Refer to section 11.1.2 for verification of proper oil pan installation.

3.10 VENTILATING SYSTEM

Vapors, formed within the engine, are removed from the crankcase, gear train and valve compartment by a continuous pressurized ventilating system.

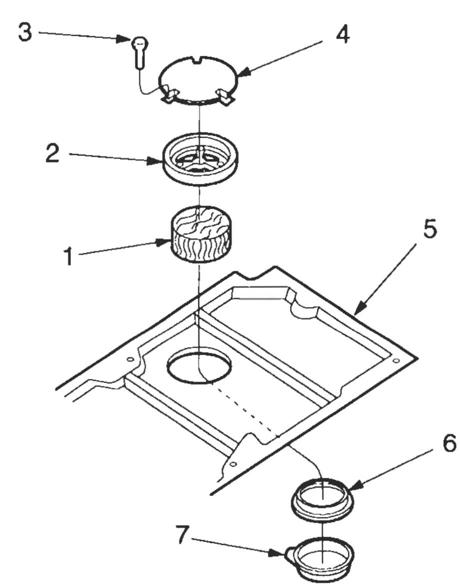
A slight pressure is maintained in the engine crankcase by the normal seepage of a small amount of air and combustion gases past the piston rings. These gases are swept up through the engine and pass through a crankcase breather. The gases are then vented to the atmosphere.

Breather extension hoses may be required on certain Series 50 engines used in on-highway vehicle applications.

Under certain conditions, the vapors from an operating engine may be circulated through the battery charging alternator by the alternator cooling fan. Excessive ingestion of vapors may lead to alternator malfunction. This can occur if the internal components of the alternator become coated with oil-laden dust or road grit.

To minimize the potential for this condition, check the length of the engine breather tube and add an extension hose, if necessary. For proper dissipation of vapors, the end of the breather hose *must* extend at least twelve inches below the oil pan rail.

A wire mesh element is located inside the valve cover, or in a separate housing on the valve cover cap or at the gear case cover. This element traps excess engine oil particles in the vapor and returns them to the crankcase. See Figure 3-31.



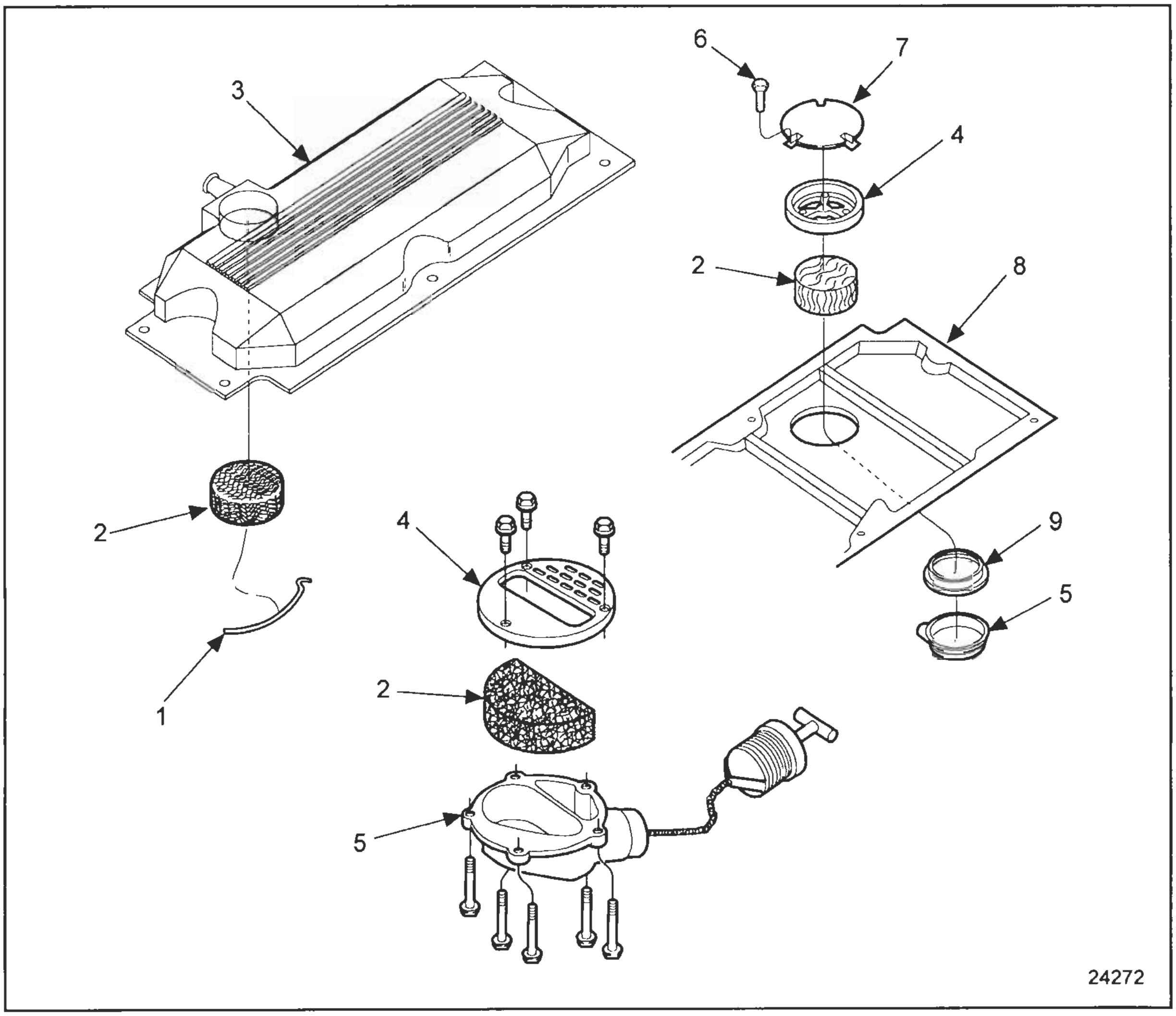
24371

1. Wire Mesh Element
2. Retainer
3. Screw
4. Baffle
5. Valve Cover Cap
6. Seal
7. Breather Housing

Figure 3-31 Wire Mesh Elements

A new baffle (23515095) has been added to the breather assembly on the two-piece, low profile aluminum valve rocker cover used on Series 50 engines. This change went into production on June 29, 1993, effective with unit serial number 04R001729. The change was also made to unit 04R001001 (built June 5, 1993) on a singe engine pre-production basis.

The new baffle redirects oil splash from the rocker arms, preventing oil from loading the breather element. See Figure 3-32. Oil trapped in the breather medium can drip out of the breather tube and may cause faulty high crankcase pressure readings.



1. Breather Housing
2. Wire Mesh Element
3. Retainer
4. Rocker Cover
5. Baffle
6. Valve Cover Cap
7. Seal

Figure 3–32 Breather Component Location

3.10.1 Repair or Replacement of Ventilating System

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 3–33.

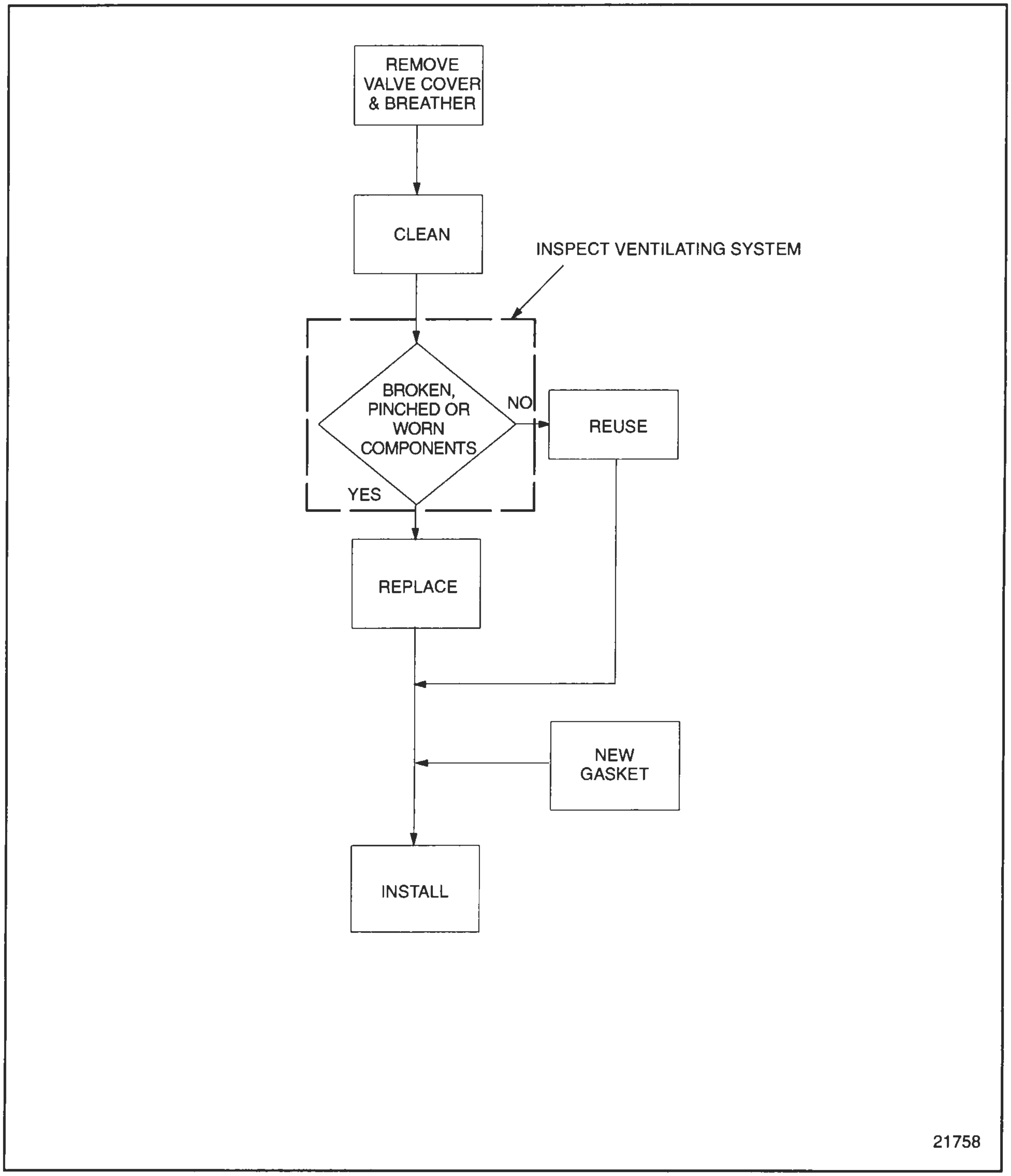


Figure 3–33 Flowchart for Repair or Replacement of Ventilating System

3.10.2 Cleaning and Removal of Ventilating System

Precleaning is not necessary.

Remove ventilating system as follows:

1. The two-piece low profile valve rocker cover cap has a removable breather housing. Remove as follows:
   [a] Remove the valve cover. Refer to section 1.6.2.
   [b] Remove the three screws, baffle and retainer that retains the breather housing.
   [c] Remove the breather housing, seal, and wire mesh element.
2. If the engine is equipped with a gear case cover breather, remove as follows:
   [a] Remove the 5 bolts that secure the breather-oil fill housing to the gear case cover. See Figure 3-34.

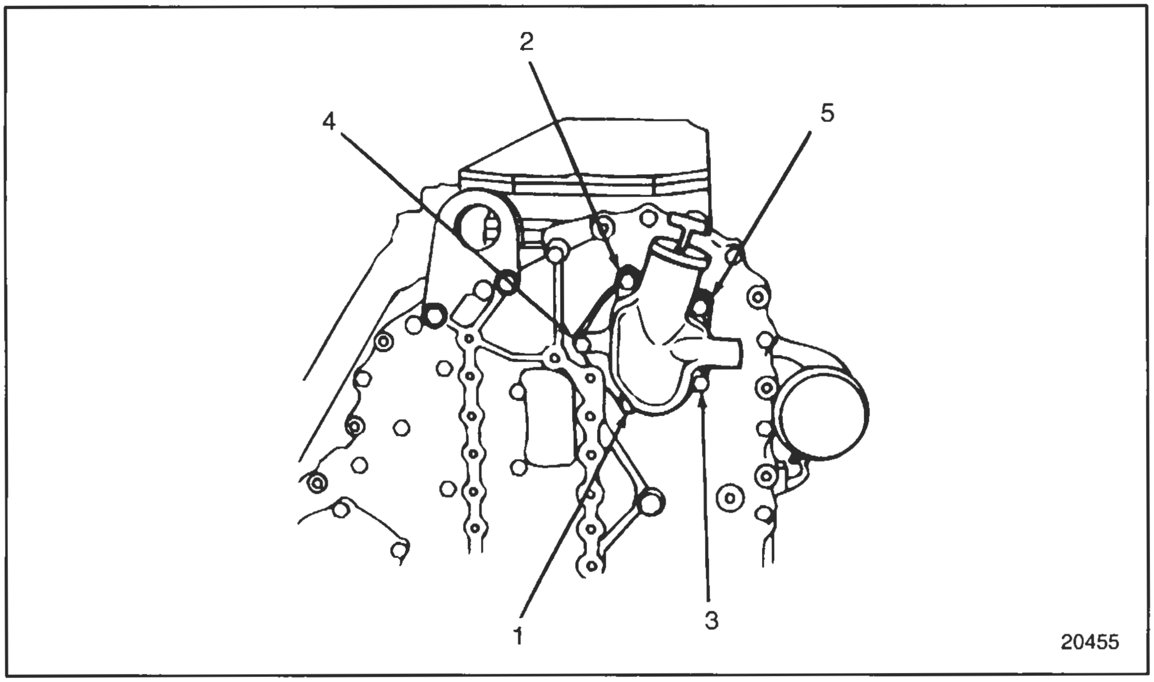
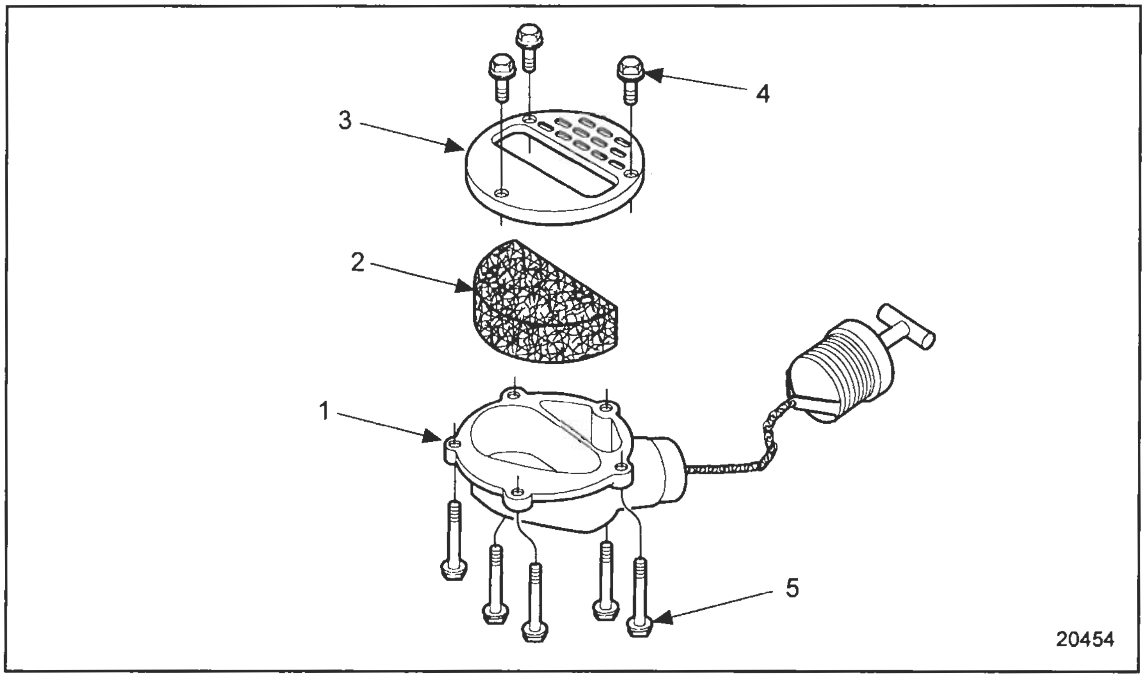


Figure 3-34 Breather/Oil Fill Tightening Sequence

[b] Remove the 3 screws that secure the retainer to the housing. See Figure 3-35.



1. Breather Housing
2. Wire Mesh Element
3. Retainer
4. Retainer Bolts
5. Housing Bolts

Figure 3–35 Breather/Oil Fill Housing

[c] Remove the retainer and wire mesh element from the breather housing.

3.10.2.1 Inspection of Ventilating System

Clean the wire mesh element components prior to inspection as follows:

1. Wash the components in clean fuel oil.

> **CAUTION:**
>
> **To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.**

2. Blow dry with compressed air.
3. Clean all old gasket material from the mating surfaces of the breather/oil fill housing and the gear case cover.

Inspect the ventilating system as follows:

1. Inspect the ventilating system for damaged parts.
   [a] Check components for pinched, broken, worn, and unclean parts.
   [b] If any components are damaged, replace with new parts.

3.10.3 Installation of Ventilating System

Install the ventilating system as follows:

1. Install the gear case cover mounted breather as follows:
   [a]. Install the wire mesh element in breather housing.

NOTE:
Do not leave gaps around the edges.

   [b] Install the 3 screws and retainer to breather housing. Tighten the screws to 2.5 N·m (22 lb·in.) torque.
   [c] Install new gasket, between the breather/oil fill housing and the gear case cover. Tighten the five bolts to 30–38 N·m (22–28 lb·ft) torque using the proper tightening sequence. See Figure 3–34.
2. Install the valve cover mounted breather as follows:
   [a] Install wire mesh element in valve cover.
   [b] Install retaining clip in valve cover by engaging curved end in valve cover and then engaging straight end.
   [c] Place the baffle on the retainer with 3 flat bolting flanges against the retainer.

NOTE:
The baffle must be installed with bolting flanges against the retainer to permit proper engine breathing.

   [d] Install the 3 screws into baffle and tighten to 2.5 N·m (22 lb·in.) torque.
   [e] Install seal and breather housing in valve cover.
3. Install valve covers. Refer to section 1.6.3.

3.A ADDITIONAL INFORMATION

Description **Page**

SPECIFICATIONS

Listed in Table 3–1 are the exceptions to standard fastener torque specifications.

Fastener	Size	Torque, (N·m) lb·ft
Bolt, Oil Pump–to–Balance Shaft Support	M10 x 1.5	58–66 (43–49)
Bolt, Oil Pan–to–Block	M10 x 1.5	25–30 (18–22)
Bolt, Oil Pump Idler Gear (Left–Hand Thread)	M14 x 2.0	200–230 (147–170)
Bolt, Tube Bracket–to–Inlet Tube	M10	47 (35)

Table 3–1 Exceptions To Standard Fastener Torque Specifications

SERVICE TOOLS

Listed in Table 3–2 are the service tools used in this section.

TOOL NO.	TOOL NAME
J 23432	External Snap Ring Pliers
J 29917	Oil Filter Wrench
J 39769	Oil Pump Idler Shaft Wrench
J 39816	Oil Pump Gear Holding Tool
J 39814	Transmission Jack Stand

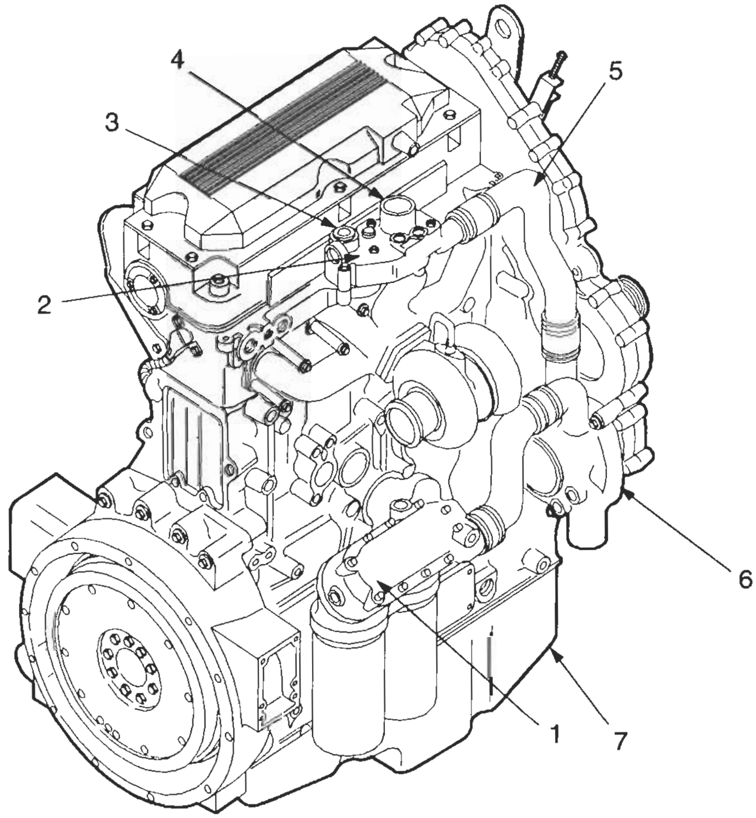
Table 3–2 Service Tools

4 COOLING SYSTEM

4.1 COOLING SYSTEM OVERVIEW

The cooling system consists of the following components (see Figure 4-1):

- ❑ Water pump
- ❑ Pressure control cap
- ❑ Thermostat
- ❑ Engine coolant fan
- ❑ Coolant filter and conditioner
- ❑ Radiator



1. Oil Cooler Housing
2. Thermostat Housing
3. Vent Line Outlet
4. Water Outlet (To Radiator)
5. Water Bypass Tube
6. Water Pump
7. Oil Pan

Figure 4–1 Cooling System Operation

An OEM supplied radiator along with a factory installed thermo-modulated fan are used to effectively dissipate the heat generated by the engine. A centrifugal-type water pump is used to circulate the engine coolant.

Two full blocking-type thermostats are used in the water outlet passage to control the flow of coolant, providing fast engine warm-up and regulating coolant temperature. Listed in Table 11-2 are the normal cooling system operational parameters.

The pressurized engine coolant is drawn from the lower portion of the radiator by the water pump and is forced through the oil cooler and into the cylinder block. See Figure 4-2.

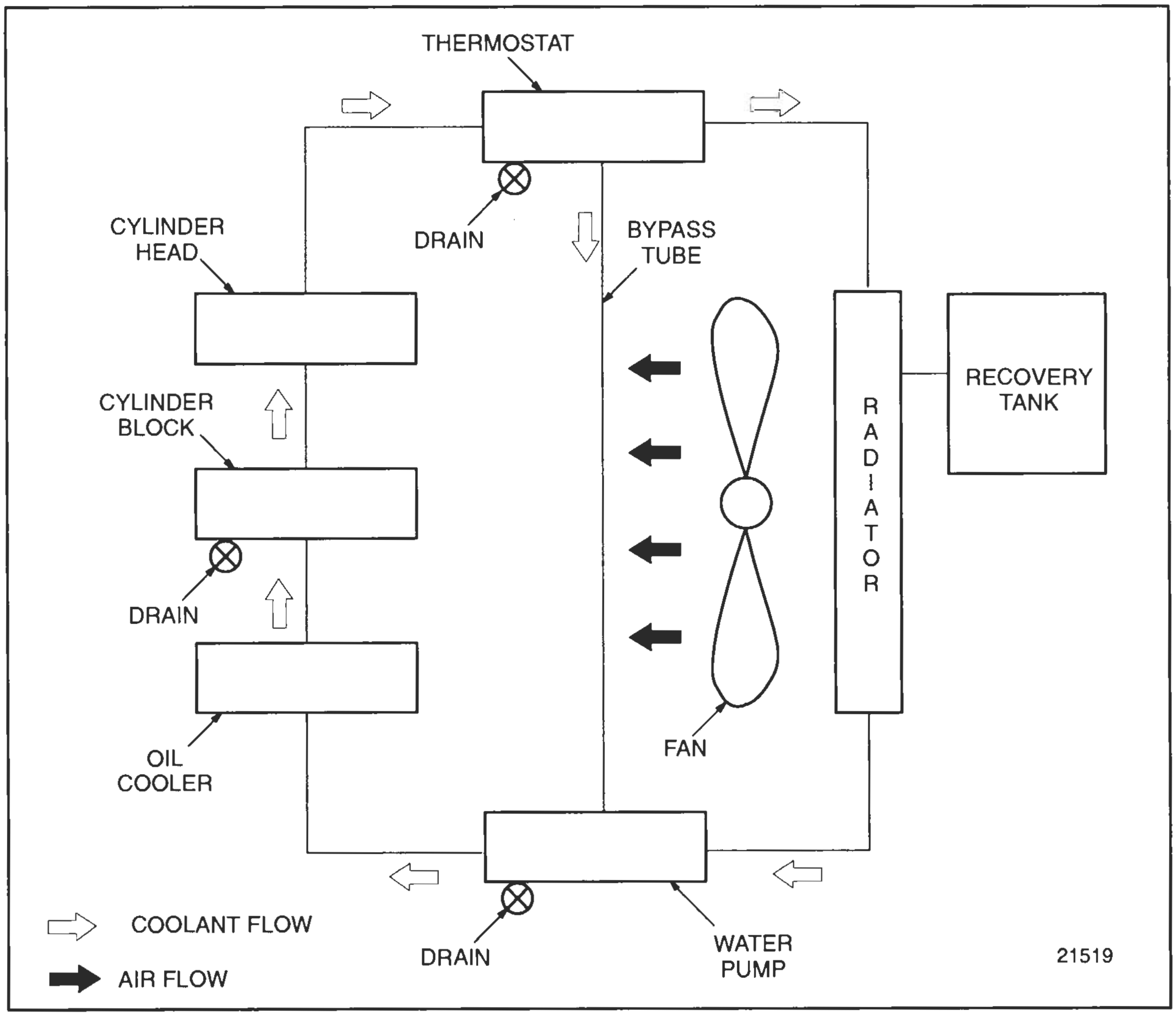


Figure 4-2 Coolant Flow Schematic

When the engine is at normal operating temperature, the coolant passes from the cylinder block up through the cylinder head, through the thermostat housing and into the upper portion of the radiator. The coolant then passes through a series of tubes where the coolant temperature is lowered by the air flow created by the revolving fan and the motion of the vehicle.

Upon starting a cold engine or when the coolant is below operating temperature, the closed thermostats direct coolant flow from the thermostat housing through the bypass tube to the water pump. Coolant is recirculated through the engine to aid engine warm-up. When the thermostat opening temperature is reached, coolant flow is divided between the radiator inlet and the bypass tube. When the thermostats are completely open, all of the coolant flow is to the radiator inlet.

The function of the engine coolant is to absorb the heat, developed as a result of the combustion process in the cylinders, from component parts such as the valves and pistons which are surrounded by water jackets. In addition, the heat absorbed by the oil is also removed by the engine coolant in the oil-to-water oil cooler. Refer to section 5 for coolant recommendations.

A pressurized cooling system permits higher temperature operation than a non-pressurized system. It is essential that the cooling system is kept clean and leak-free, that the filler cap and pressure relief mechanisms are properly installed and operate correctly, and that the coolant level is properly maintained.

As the engine temperature increases, the coolant and air in the system starts to expand and build pressure. The valve in the radiator pressure cap unseats and allows the coolant to flow into the coolant recovery tank. See Figure 4–3.

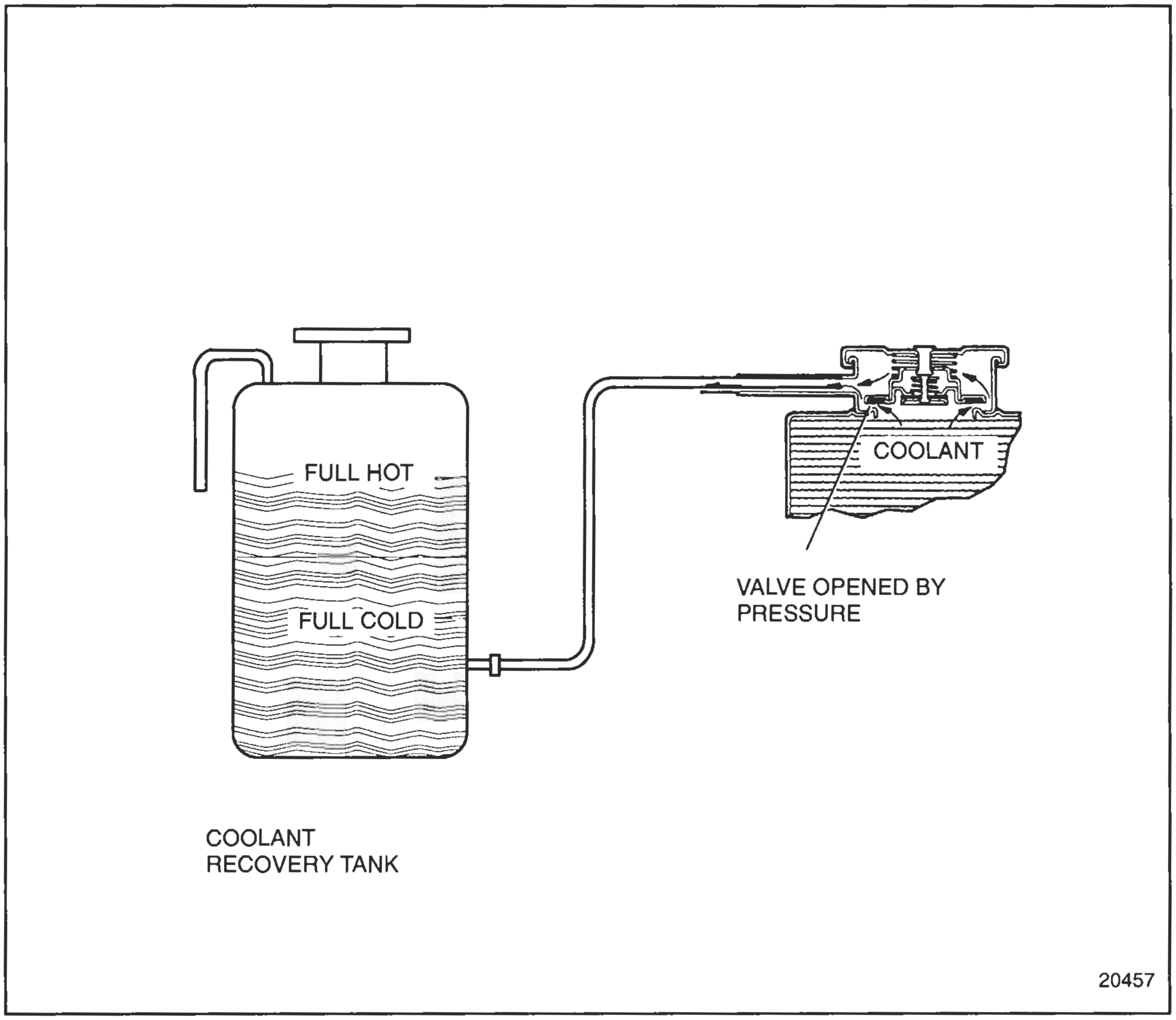


Figure 4–3 Coolant Expansion

When the engine starts to cool down, the air and coolant contract, causing a void and creating a vacuum in the system. The vacuum unseats another valve in the radiator pressure cap, allowing the coolant to flow back into the expansion tank or radiator. See Figure 4-4.

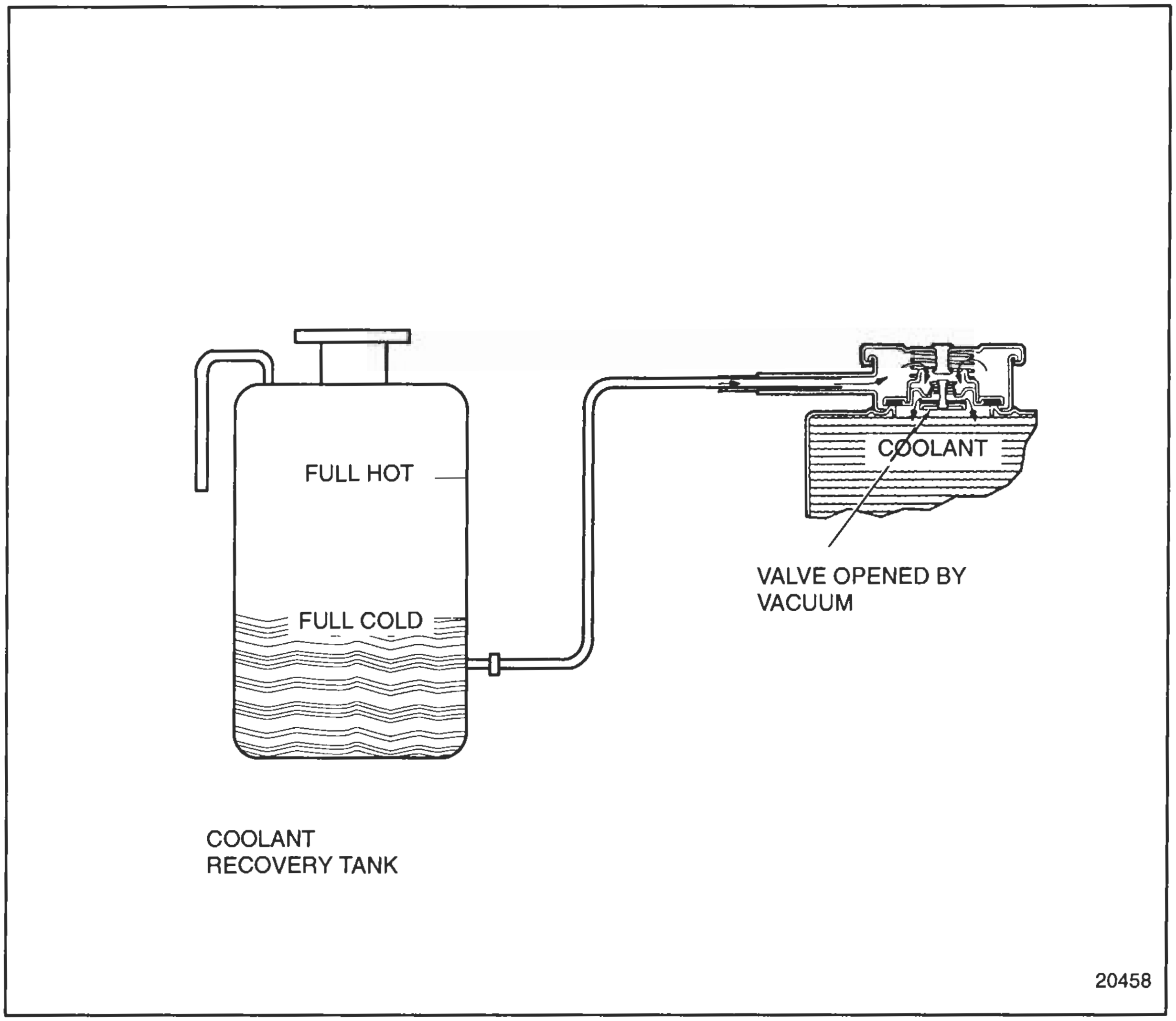


Figure 4–4 Coolant Recovery

4.2 WATER PUMP

The centrifugal–type water pump circulates the engine coolant through the cooling system.

The pump is mounted on the rear of the gear case and is driven by the water pump drive gear. See Figure 4–5. The water pump drive gear meshes with the bull gear.

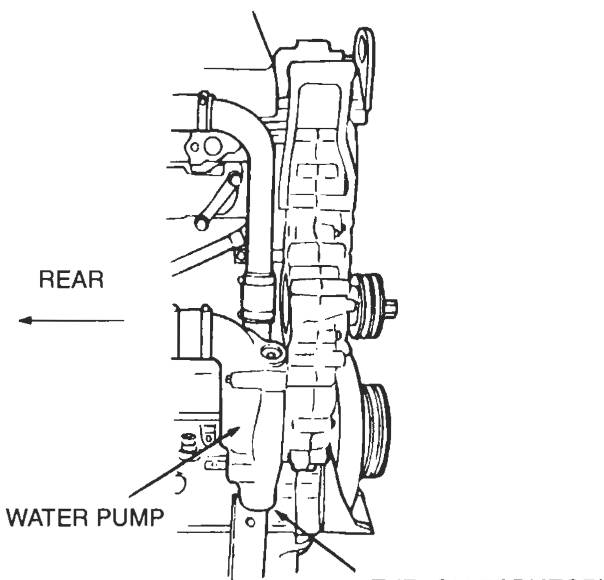
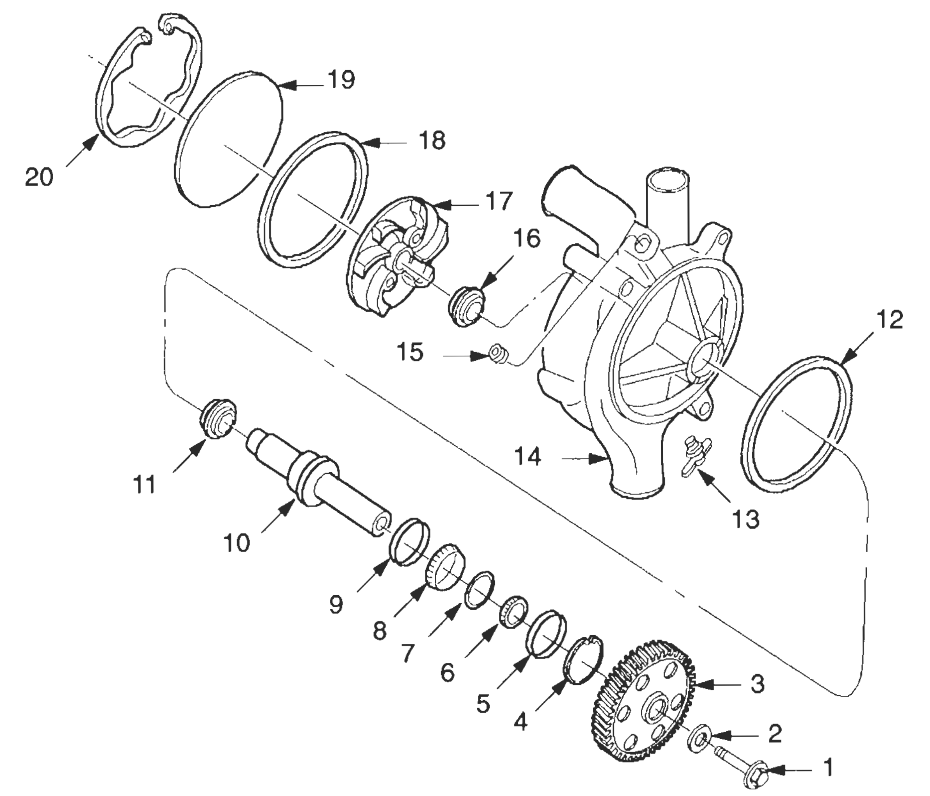


Figure 4–5 Water Pump Mounting

An impeller is pressed on one end of the stainless steel drive shaft. The other end of this shaft has internal threads, and a retaining bolt secures the water pump drive gear to the shaft. Two identical roller bearing assemblies are used to support the shaft. See Figure 4–6.



1.	Retaining Bolt	11.	Oil Seal
2.	Washer	12.	Rectangular Ring, Water Pump Housing
3.	Gear, Water Pump Drive	13.	Drain Cock
4.	Snap Ring	14.	Housing, Water Pump
5.	Bearing Race	15.	Pipe Plug, Water Pump Housing
6.	Roller Bearing, Small	16.	Water Seal
7.	Spacer Rings	17.	Impeller
8.	Roller Bearing, Large	18.	O–ring, Water Pump Cover
9.	Bearing Race	19.	Water Pump Cover
10.	Drive Shaft	20.	Snap Ring, Water Pump Cover

Figure 4–6 Water Pump Details and Relative Location of Parts

A rectangular rubber ring, located in a groove in the water pump housing, seals the water pump to the gear case. An O–ring, located under the water pump cover, seals the cover to the water pump housing. The water pump bearings are lubricated by splash oil through a passage from the front of the pump housing.

An oil seal is located behind the bearing assemblies, and a unitized, spring–loaded, face type water seal is used behind the impeller. This seal prevents water from leaking down the shaft and into the gear case. It also prevents lubricating oil from entering the cooling system. The water and oil seals cannot be replaced without removing the water pump from the engine.

4.2.1 Repair or Replacement of Water Pump

To determine if repair or replacement is necessary, perform the following procedure. See Figure 4-7.

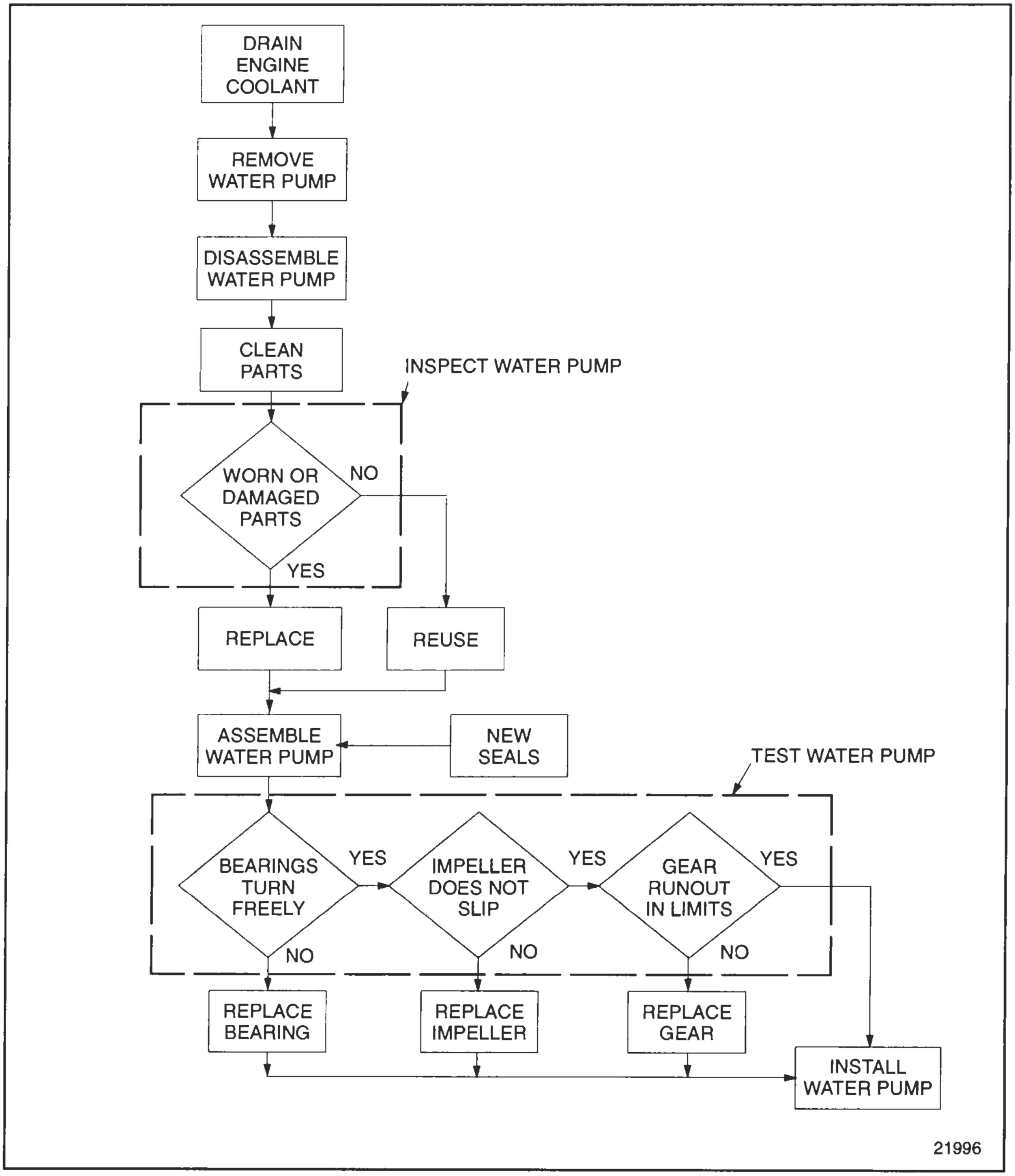


Figure 4-7 Flowchart for Repair or Replacement of Water Pump

4.2.2 Draining and Removal of Water Pump

Drain the cooling system before removal of the water pump as follows:

1. Open the drain cocks located at the right rear corner of the engine at the bottom of the water pump and in the thermostat housing.

Remove the water pump as follows:

1. Loosen the hose clamps and remove the coolant hoses from the water pump housing.
2. Loosen and remove the three water pump housing-to-gear case bolts. Remove the water pump from the engine by pulling it straight out of the gear case.

4.2.3 Disassembly of Water Pump

Disassemble the water pump as follows:

CAUTION:
Due to the size and tension of the ring, use snap ring pliers of a type to ensure maximum safety. Wear adequate eye protection, and press a hammer against the pump cover to help prevent personal injury, should the snap ring slip off the pliers.

1. Remove water pump cover snap ring with snap ring pliers, J 22380 or equivalent. Remove water pump cover and seal ring.

NOTICE:
When clamping gears, use soft jaws on vise to prevent damage to the gear teeth.

2. Clamp the water pump drive gear in a vise, with the impeller facing up. Use a two-screw gear puller and remove the water pump impeller from the shaft, using the two threaded holes in the impeller.
3. Hold square end of water pump shaft and remove water pump drive gear retaining bolt and washer. See Figure 4-8.

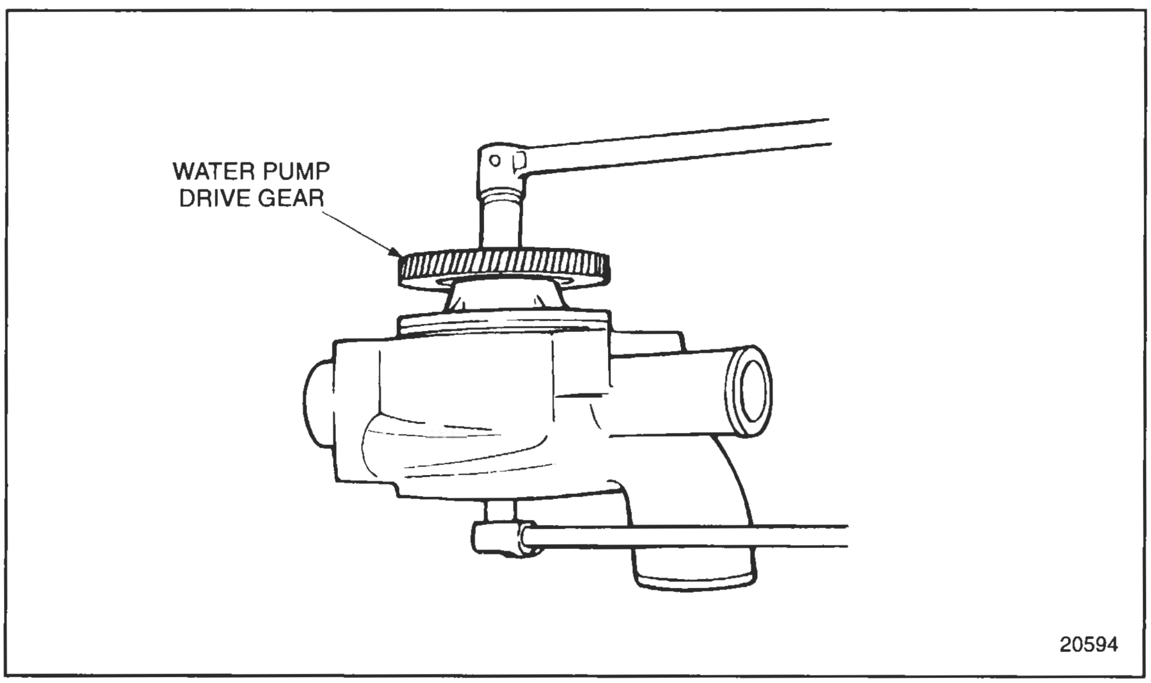


Figure 4-8 Water Pump Drive Gear Retaining Bolt Removal

4. Use a two–jaw gear puller to remove the water pump drive gear from the drive shaft.

NOTE:
The water pump drive gear may be a slip fit on the drive shaft because of manufacturing tolerances.

5. Remove the snap ring from the water pump housing. See Figure 4–9.

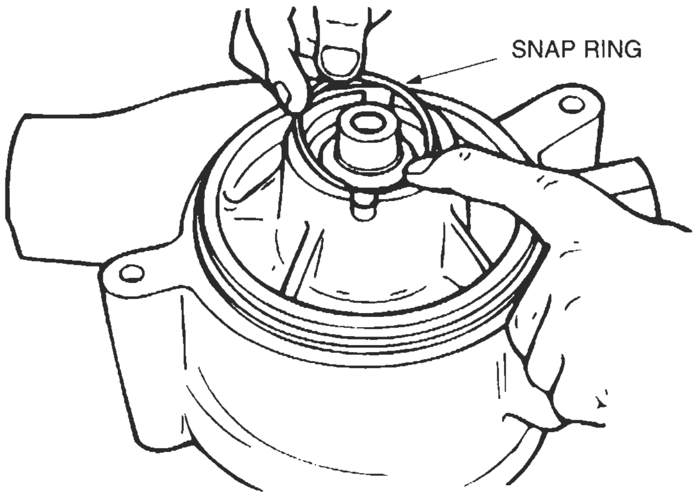


Figure 4–9 Snap Ring Removal

6. Support the water pump housing, engine side down, using steel blocks or plates, to allow at least 76 mm (3 in.) of clearance between the pump housing and the press bed.
7. Press the drive shaft and bearings assembly out through the front (engine side) of the water pump housing, until both bearing races are clear of the housing.

NOTE:
Once the bearing assemblies are pressed out of the water pump housing, they must be replaced with new assemblies.

NOTICE:
Do not allow brass drift to score housing bore when tapping out seals. A scored bore will cause coolant leaks and can damage engine.

8. Remove both the water and oil seals from the housing using a brass drift and hammer.

9. Support the drive shaft assembly on two steel blocks, at the bearing inner race.
10. Insert extension tool, J 35988-3A, part of tool set J 35988-B, in end of drive shaft. See Figure 4-10.

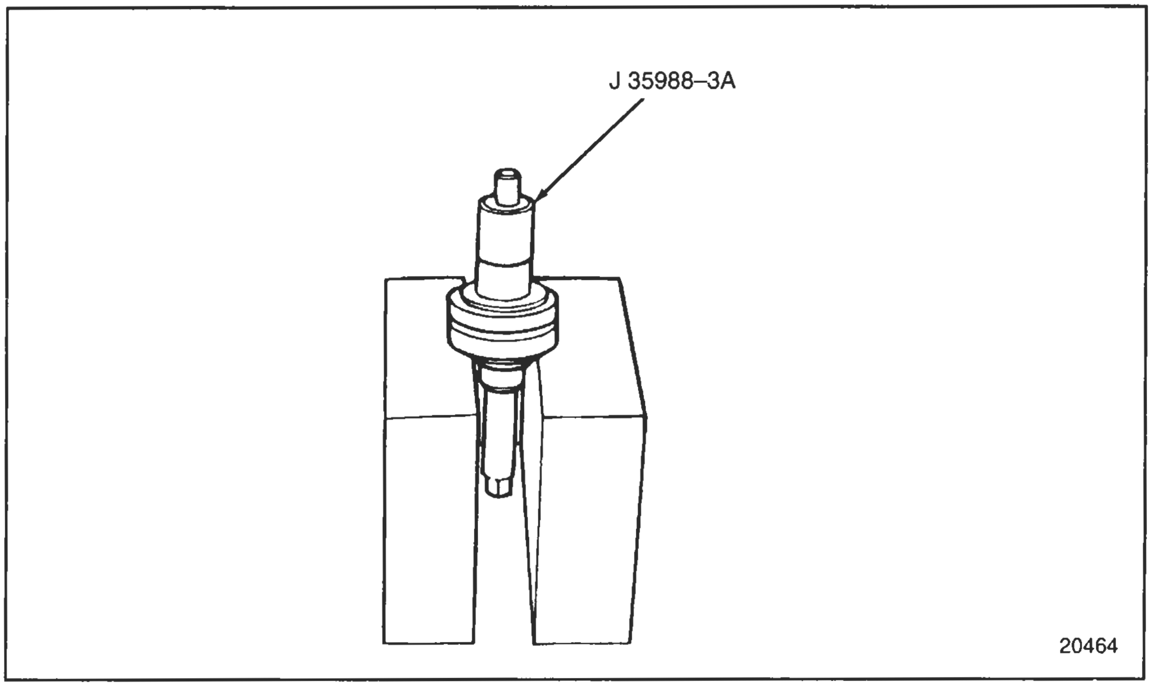


Figure 4-10 Removing Bearing Assemblies

11. Press the drive shaft out until it is clear of both bearing and race assemblies. Discard the used bearings, races and the two spacer rings located between the bearing packs.

4.2.3.1 Inspection of Water Pump

Inspect the water pump parts as follows:

1. Wash all of the pump parts in clean fuel oil.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

2. Dry the parts with compressed air.
3. Visually inspect the water pump housing, cover O–rings and all other water pump parts for cracks, wear or other damage.
   [a] Replace damaged or worn parts.
   [b] Reuse remaining components.
4. Replace the twin bearing assemblies, the oil seal and water seal.

4.2.4 Assembly of Water Pump

Assemble the water pump as follows:

1. Coat the bearing bores of the water pump housing and the drive shaft bearing surfaces with clean engine oil.

NOTICE:
Although the bearings are identical, the bearings and races are matched parts, and should be installed as they are removed from the box. Parts that are not matched will cause damage to the water pump.

2. Assemble the new bearing packs, as follows:
   [a] Place the small spacer ring on the inner bearing race. See Figure 4–11.
   [b] Place the larger spacer ring on the outer bearing race.

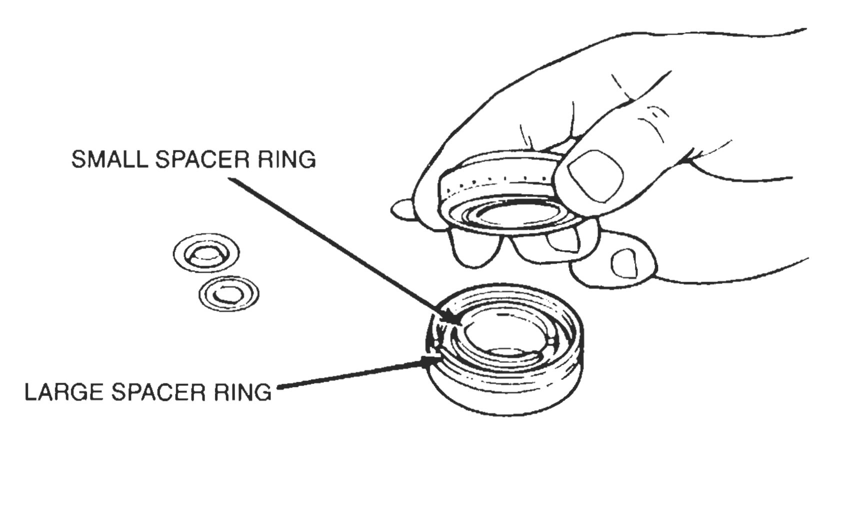


Figure 4–11 Bearing Pack Assembly

3. Using the drive shaft support tool, J 35988–18 and the water pump fixture J 35988–2, parts of tool set J 35988–B. Install the support tool into the center of the fixture. See Figure 4–12.

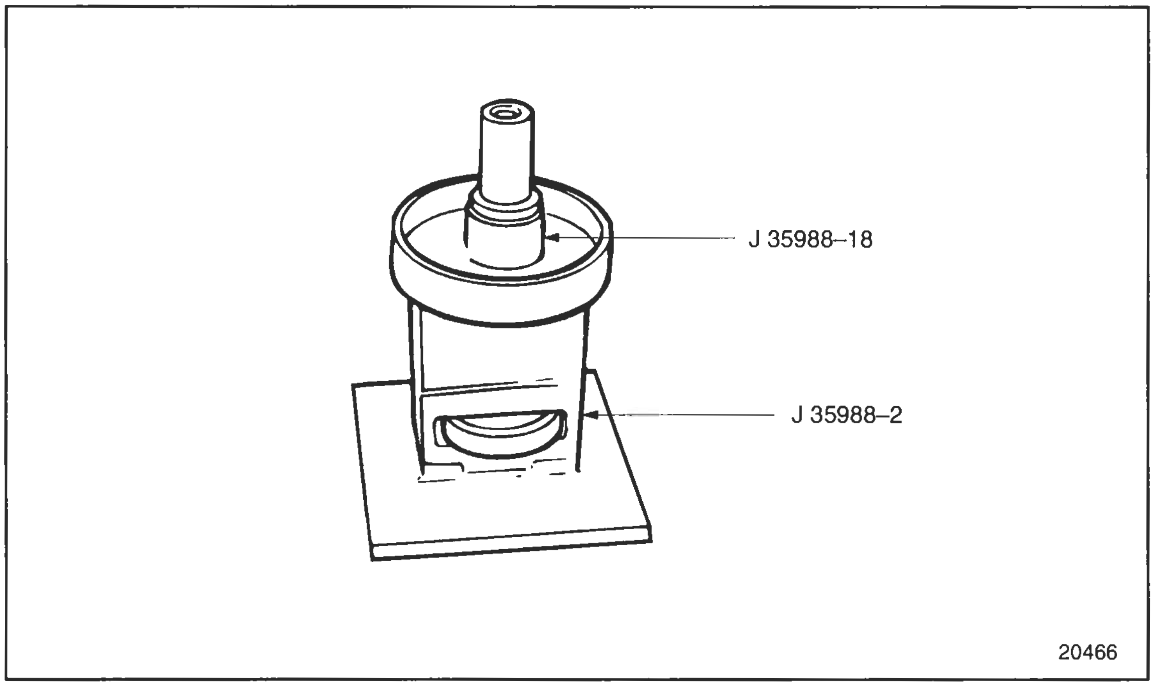


Figure 4–12 Bearing Installation Set–Up

4. Install the extension tool, J 35988–3A part of tool set J 35988–B, on the end of the water pump shaft. Install the assembled bearing packs to the drive shaft. See Figure 4–13.

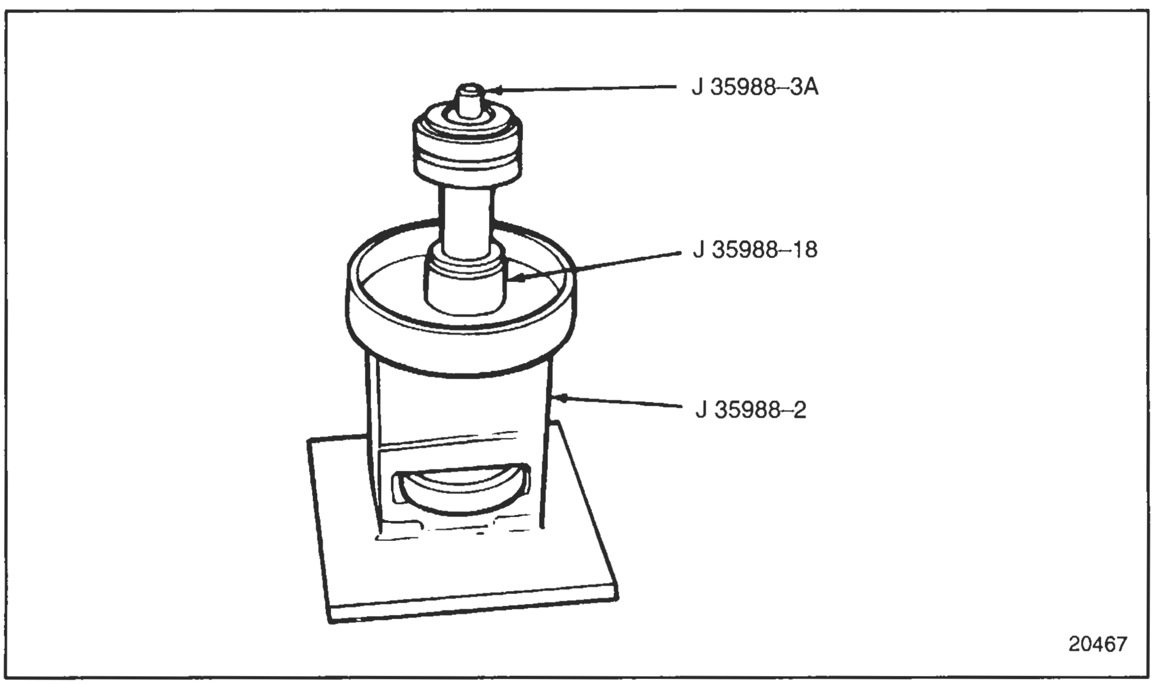


Figure 4–13 Bearing Placement

5. Center the small end of tool J 35988–1, part of tool set J 35988–B, on the bearing inner race. See Figure 4–14. Press the bearing pack onto the shaft until it contacts the shoulder of the shaft. Remove the tool used to pilot the bearings.

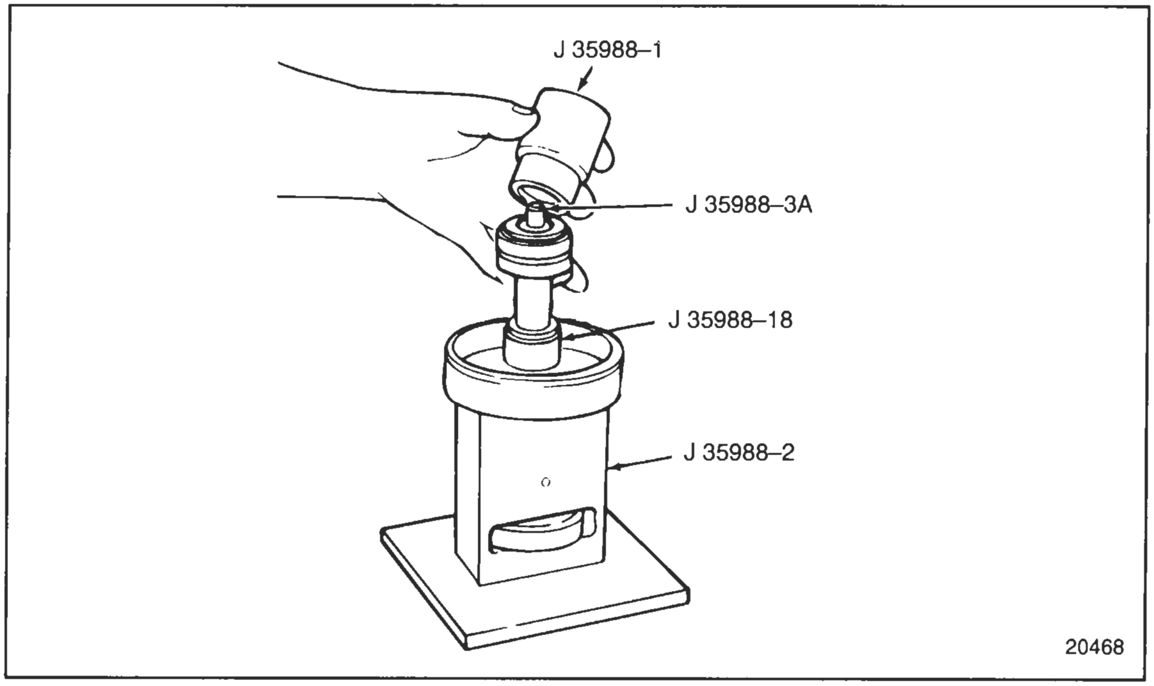


Figure 4–14 Bearing Installation

6. Remove the shaft and bearing assembly from the press.

4.2.4.1 Test Bearing Assembly

Check bearing assembly as follows:

1. Turn bearings to ensure they turn freely.
2. If bearings bind, disassemble water pump and replace bearing assembly. Refer to section 4.2.3.

4.2.5 Assembly of Water Pump – cont'd

Continue assembling the water pump, as follows:

1. Coat the oil seal contact area of the water pump housing with a thin film of clean engine oil. See Figure 4-15.

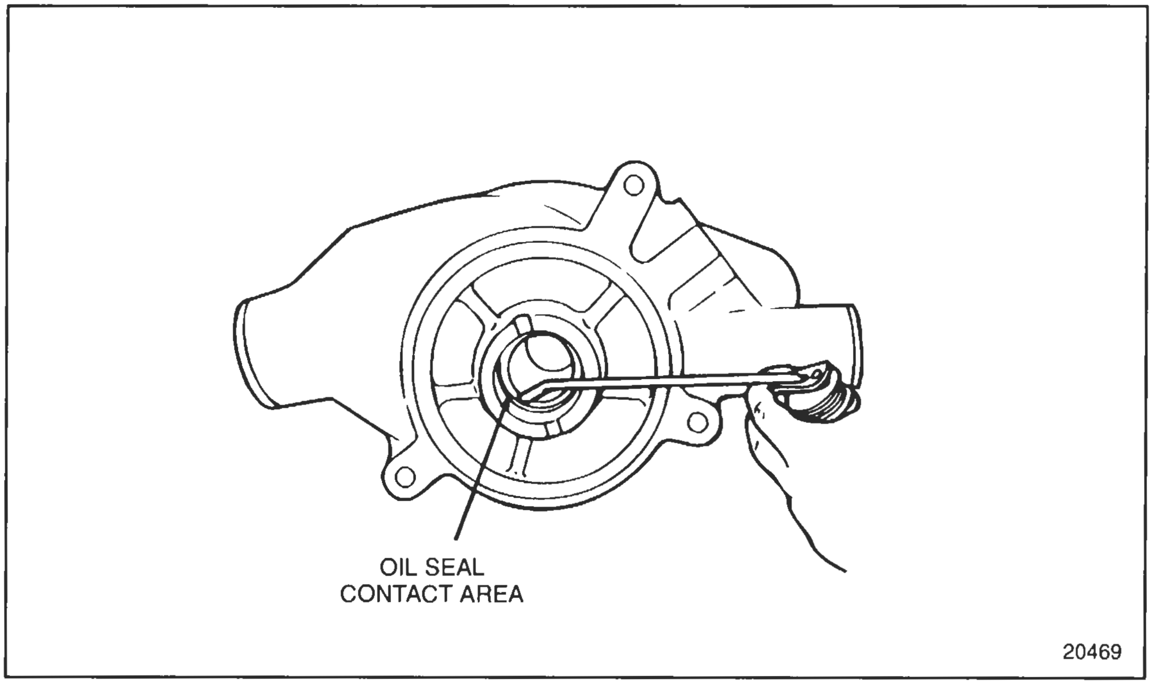


Figure 4–15 Oil Seal Contact Area Lubrication

2. Install a new oil seal into the water pump housing from the front (gear side). See Figure 4-16.

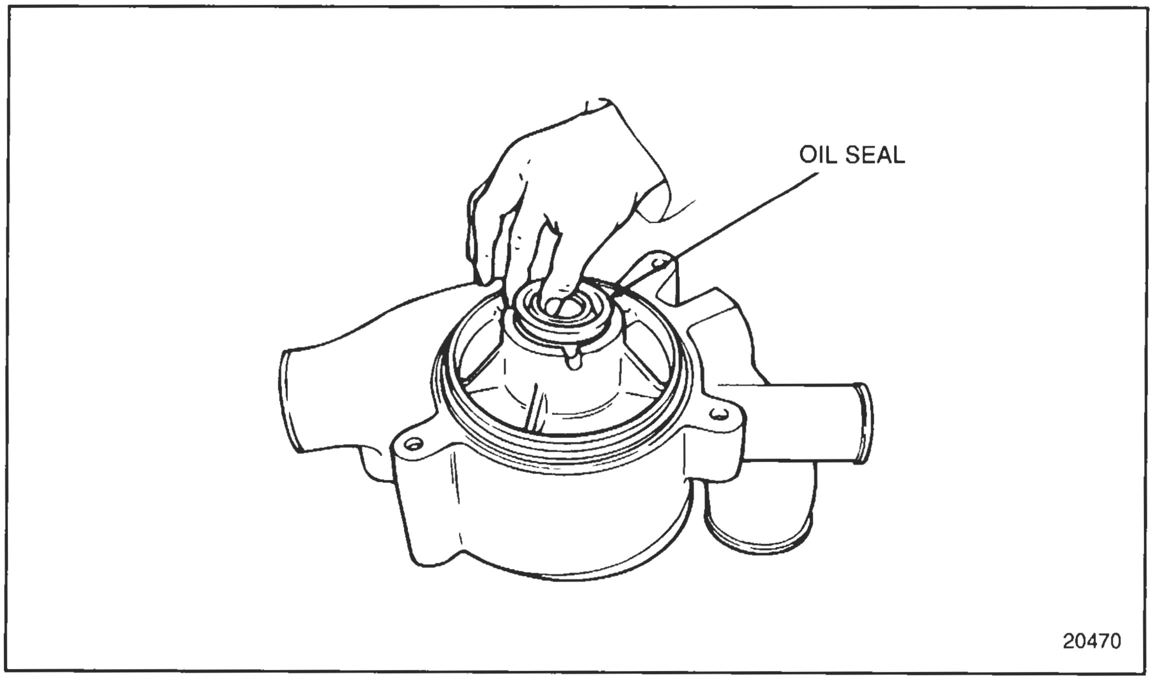


Figure 4–16 Oil Seal Positioning

NOTICE:
The contact surface of the oil seal is coated with a special sealant. Do NOT remove this sealant before installing the oil seal. If sealant is removed, leakage can occur.

3. Place the small end of tool J 35988–1, part of tool set J 35988–B, into the water pump housing until it contacts the oil seal. See Figure 4–17.

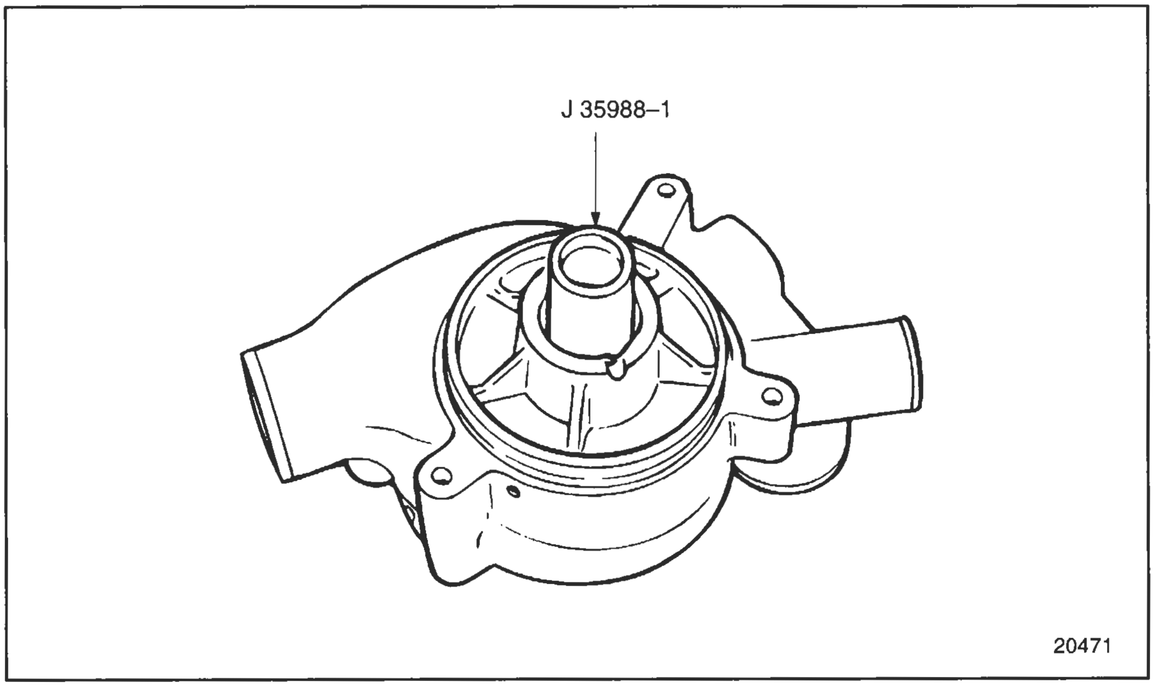


Figure 4–17 Oil Seal Installation

4. Press the oil seal into the housing until the seal lip is bottomed in the pump housing. Remove the tool J 35988–1, part of tool set J 35988–B.
5. Coat the bearings with clean engine oil.
6. Place the water pump housing, with the gear side up, on a press bed.

7. Install the drive shaft, with bearings installed, to the water pump housing. See Figure 4–18.

NOTE:
During the bearing installation, the water pump housing must be parallel to the press bed or table surface.

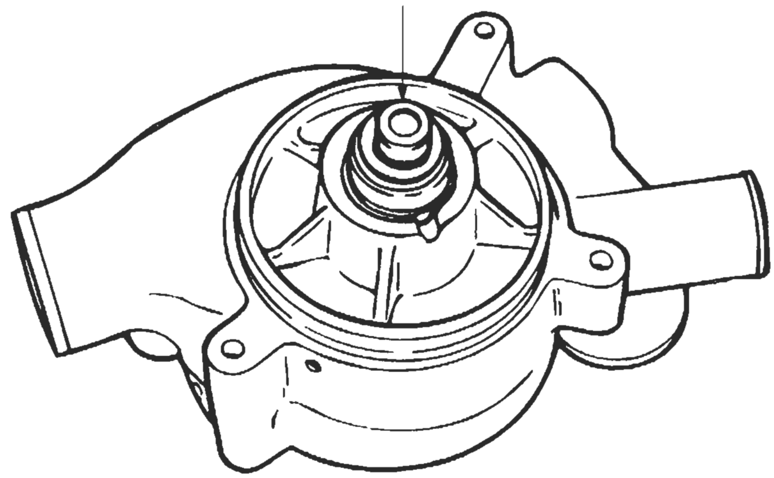


Figure 4–18 Drive Shaft Insertion

NOTICE:
The drive shaft must be installed using the outer bearing race only. Any other attempt at installation may damage the bearings.

8. Place the large end of tool J 35988–1, part of tool set J 35988–B, over the drive shaft so that the lip of the tool rests squarely on the outer bearing race. See Figure 4–19.

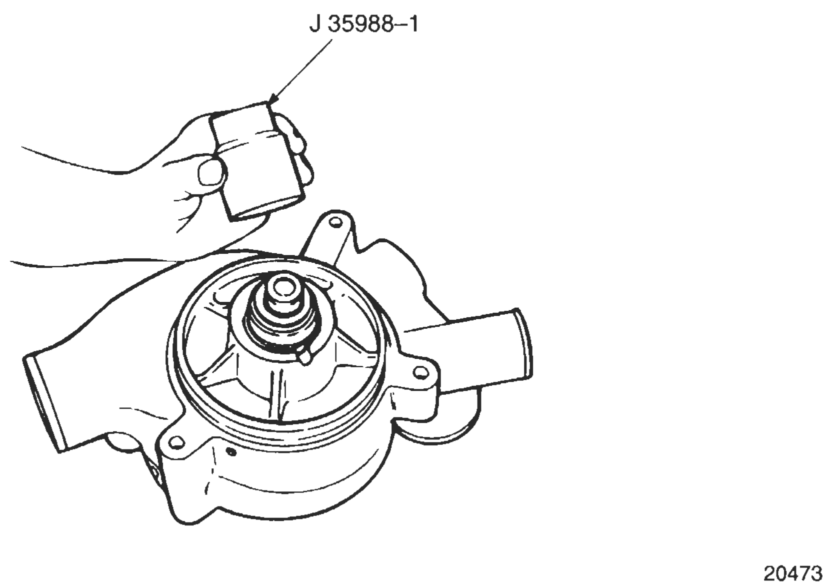


Figure 4–19 Drive Shaft Installation

9. Press the drive shaft and bearing assembly into the water pump housing, using tool J 35988–1, part of tool set J 35988–B, until it is seated firmly against the shoulder in the housing.

10. Install the snap ring to the water pump housing. See Figure 4–20.

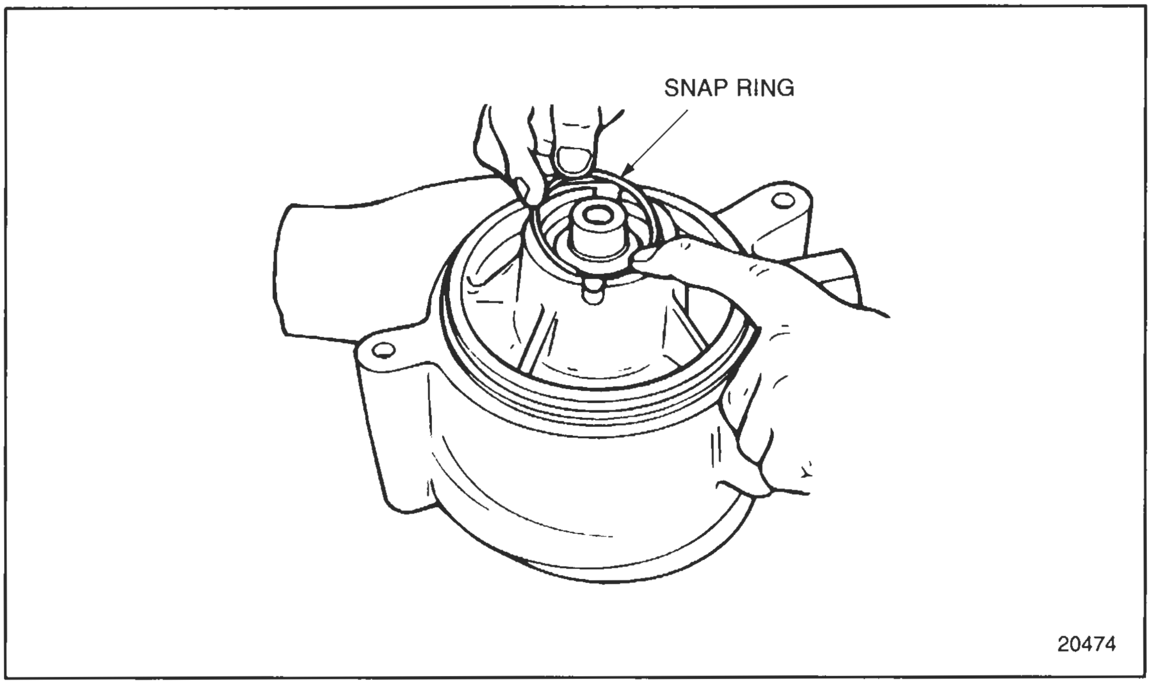


Figure 4–20 Snap Ring Installation

NOTICE:
Form–a–Gasket Sealer must be used sparingly, and kept from the shaft and bearing surfaces. Excessive amounts of Form–a–Gasket Sealer may cause plugging of radiator or cooler core.

11. Turn the water pump housing over. Working through the rear, apply a coating of Aviation Form–a–Gasket, Form–a–Gasket No. 3 or equivalent to the area where the water pump seal case contacts the pump body. See Figure 4–21.

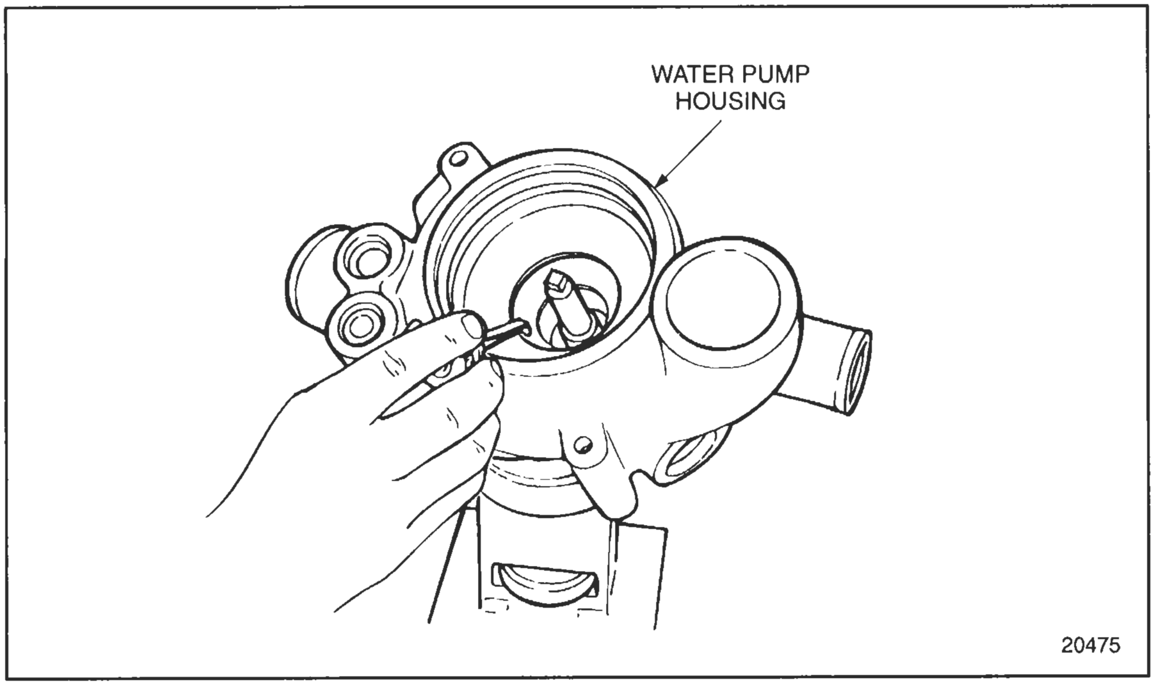


Figure 4–21 Sealer Installation

NOTICE:
The extension must contact and support the shaft when installing the water seal and impeller to prevent damage to the bearings.

12. Install the extension J 35988–3A, part of tool set J 35988–B, to the fixture tool. See Figure 4–22.

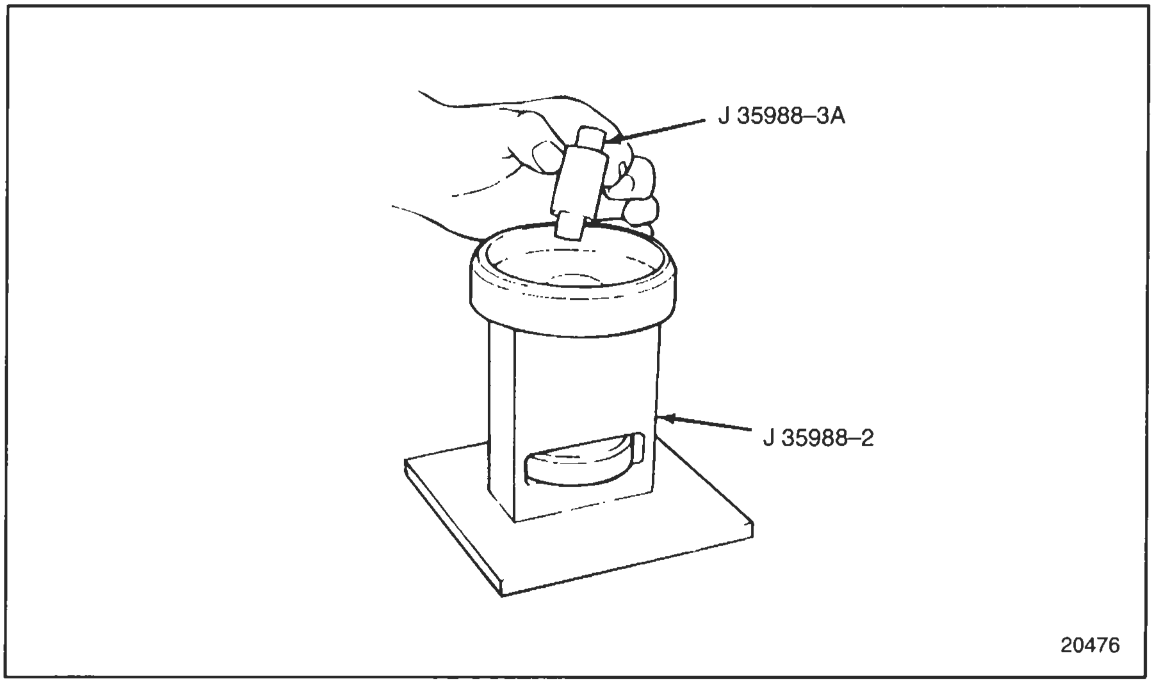


Figure 4–22 Support Installation

13. Install the water pump housing assembly to the fixture. See Figure 4–23.

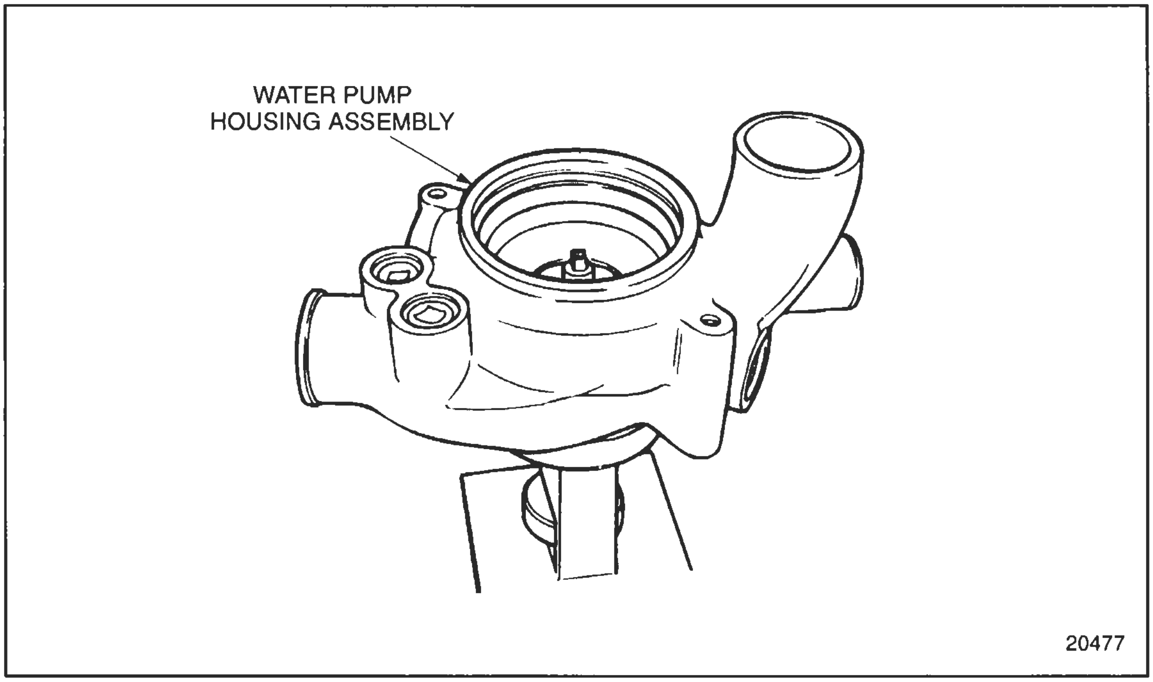


Figure 4–23 Water Pump Impeller Installation Set–up

14. Turn the adjustor wheel to raise the extension until it contacts the drive shaft in the water pump housing.
15. Apply Loctite primer (Locquic Primer N, Part No. 764) by swabbing onto the I.D. of the rotor of the seal.
16. Install a new water seal over the drive shaft and seat it in the water pump housing. See Figure 4–24.

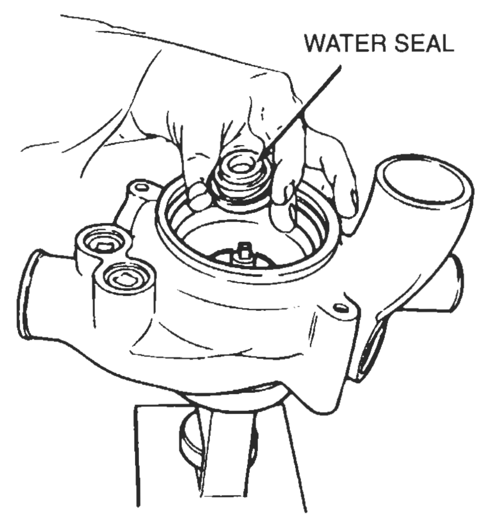


Figure 4–24 Water Seal Insertion

17. Position seal installer J 35517–1, part of tool set J 35988–B over the water seal. See Figure 4–25.

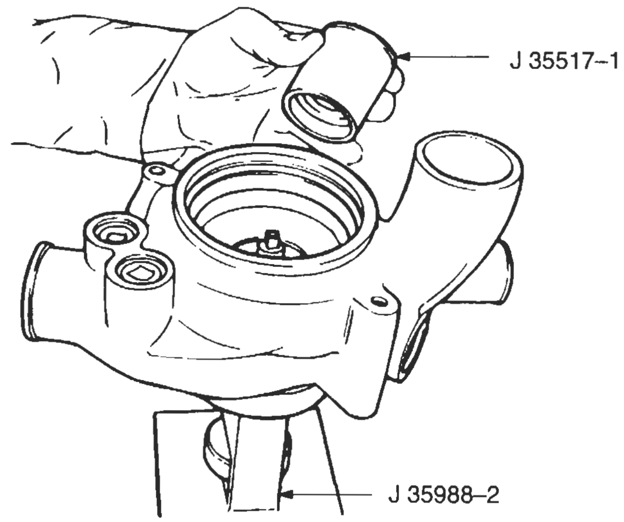


Figure 4–25 Water Seal Installation

18. Press the water seal into the housing until the flange of the seal case contacts the water pump housing a full 360°. Remove tool J 35517–1, part of tool set J 35988–B.

NOTICE:

The shaft should not be turned, moved from vertical or the seal pressure tested for at least two hours. Do not exceed 172 kPa (25 lb/in.^{2}) when pressure testing. Sealant requires curing to prevent leaks and damage to engine.

NOTICE:

The Loctite 290 sealant must not be allowed to spill over the side of the water pump seal. Damage to the seal may occur.

19. Apply only one drop of Loctite 290 sealant to the drive shaft where it contacts the water seal. The sealant will wick around the shaft making a complete seal. See Figure 4–26. Wipe off excess sealant.

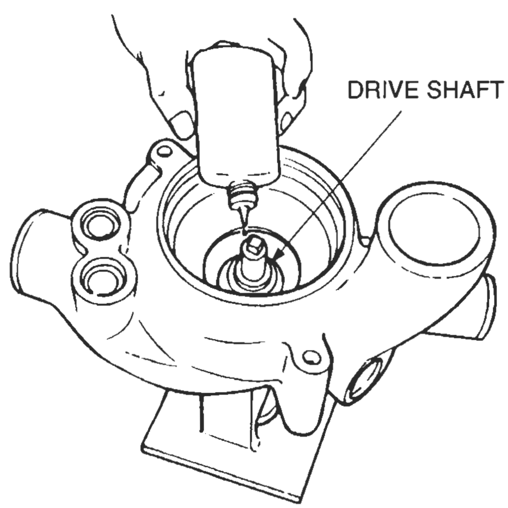


Figure 4–26 Sealant Installation

20. With the shaft in the vertical position, apply Locquic Primer N on top of the Loctite 290 by swabbing.

NOTE:
Due to time required for curing, DDC recommends keeping a pump built up in parts for immediate use when needed. A pump removed from an engine could be rebuilt and placed in storage for later use.

21. With the water pump housing still housed in tool J 35988–2, part of tool set J 35988–B, and located on a press bed, position the impeller over the square end of the drive shaft with the vanes of the impeller facing down. See Figure 4–27.

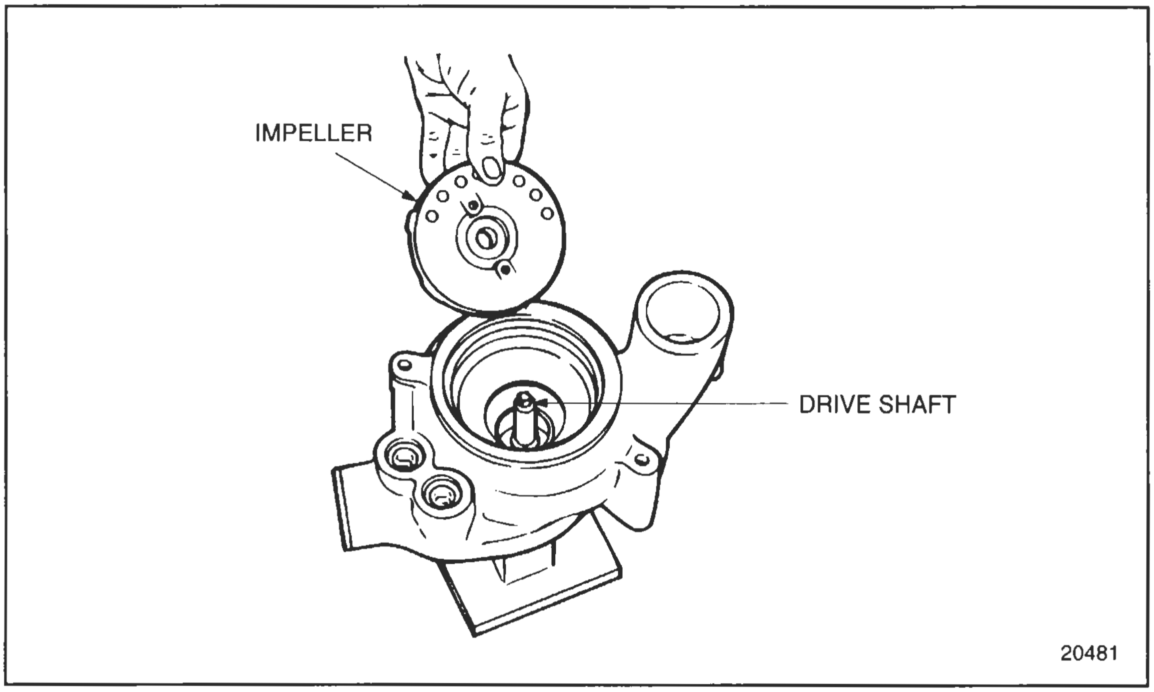


Figure 4–27 Water Pump Impeller Installation

NOTICE:
During this procedure, the drive shaft must be supported by the extension tool J 35988–3A, part of tool set J 35988–B. Failure to support the drive shaft while installing the impeller may result in bearing damage.

22. Using the impeller installation tool J 35988–14, part of tool set J 35988–B, press the impeller on until the tool is flush against the water pump body. See Figure 4–28.

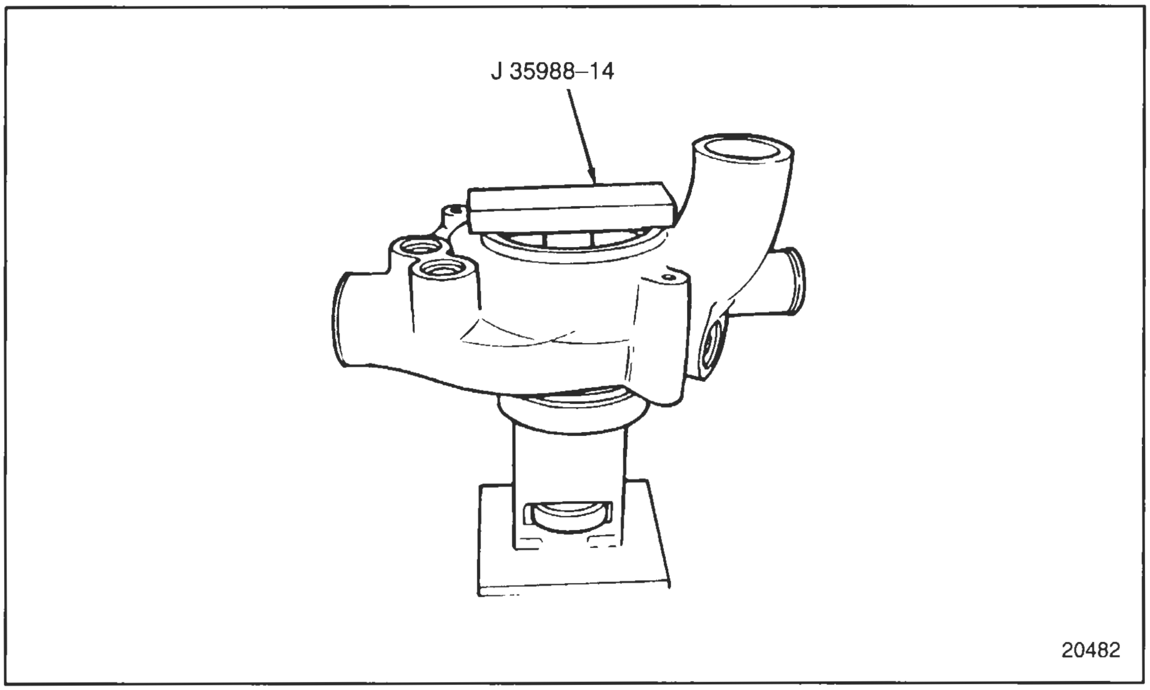


Figure 4–28 Water Pump Impeller Location

23. Turn the housing over and place it face (impeller side) down on the fixture J 35988-2, part of tool set J 35988-B. See Figure 4-29.

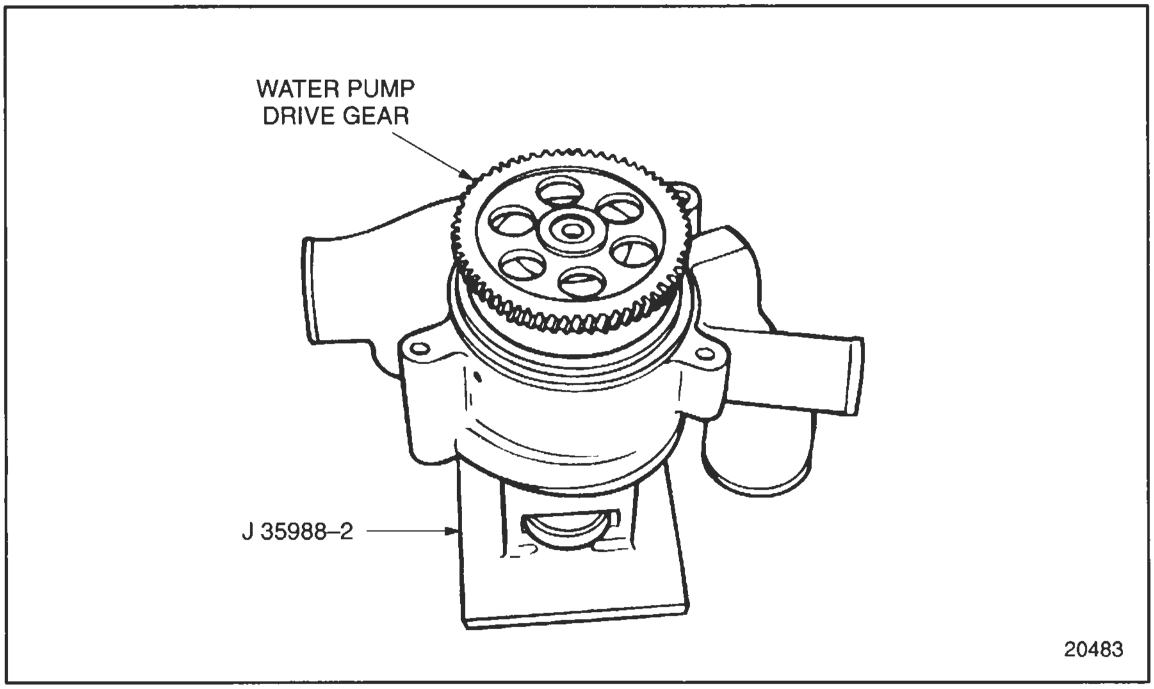


Figure 4-29 Water Pump Drive Gear Installation

24. Install the water pump drive gear to the drive shaft.

NOTE:
The water pump drive gear may have a slip fit. This is due to manufacturing tolerances and is acceptable.

NOTICE:
If the gear has a press fit, turn the adjustor wheel to raise the extension J 35988–3A, part of tool set J 35988–B, until it contacts and supports the shaft. This is necessary to prevent damage to the bearings when pressing the gear onto the shaft.

25. Using the small end of tool J 35988–1, part of tool set J 35988–B, press the drive gear down onto the drive shaft until it touches the bearings. See Figure 4–30.

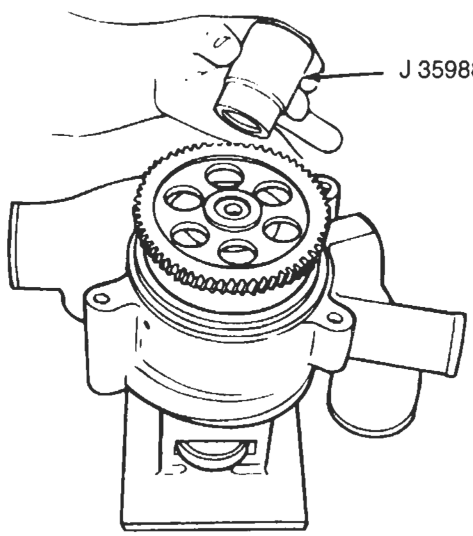


Figure 4–30 Water Pump Drive Gear Installation

26. Install the retaining bolt and washer. Hold the square end of the drive shaft and torque the retaining bolt to 101–126 N·m (75–93 lb·ft).

4.2.5.1 Assembly Integrity Test

Verify the assembly integrity as follows:

1. Turn the pump over and install the water pump impeller slip and lash tester, J 35687, into the tapped holes provided in the impeller.

NOTICE:
When clamping gears, use soft jaws on vise to prevent damage to the gear teeth.

2. Clamp the water pump drive gear in a vise, with the impeller facing up.
3. Using a 1/2 in. drive torque wrench in the hole provided in the center of the slip and lash tester, J 35687, apply 68 N·m (50 lb·ft) torque in either direction.
   [a] The impeller must withstand 68 N·m (50 lb·ft) torque without slipping.
   [b] If the torque specification is not satisfied, disassemble water pump and replace the impeller. Refer to section 4.2.3.

4. Using a dial indicator with magnetic base, measure the total runout of the water pump drive gear at four places, at 90° intervals. Maximum allowable runout is 0.0635 mm (.0025 in.). See Figure 4–31.

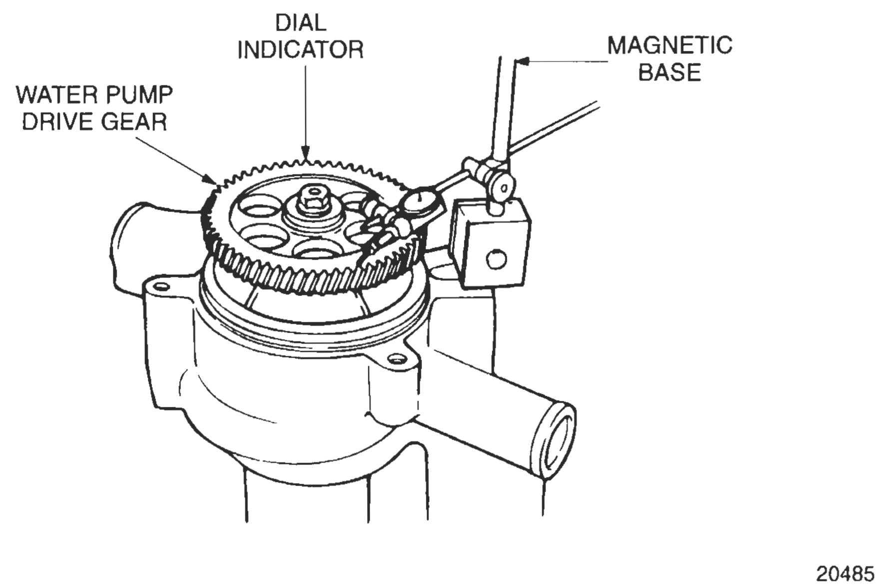


Figure 4–31 Measuring Water Pump Drive Gear Runout (GCM)

[a] If this value is exceeded, disassemble the water pump and check for burrs or foreign particles. Refer to section 4.2.3.

[b] If runout still exceeds limits, disassemble water pump and replace the drive gear or drive shaft as necessary. Refer to section 4.2.3.

5. Remove dial indicator and magnetic base.

4.2.6 Assembly of Water Pump (Continued)

Continue assembly of the water pump as follows:

CAUTION:

Due to the size and tension of the snap ring, use snap ring pliers of a type to ensure maximum safety whenever removing or installing the water pump cover snap ring. Wear adequate eye protection, and press a hammer against the pump cover to help prevent personal injury, should the snap ring slip off the pliers.

1. Install seal ring, water pump cover, and snap ring with the beveled side of snap ring facing out. Tap around the inside rim of the snap ring with a brass drift and hammer to seat snap ring in groove fully.

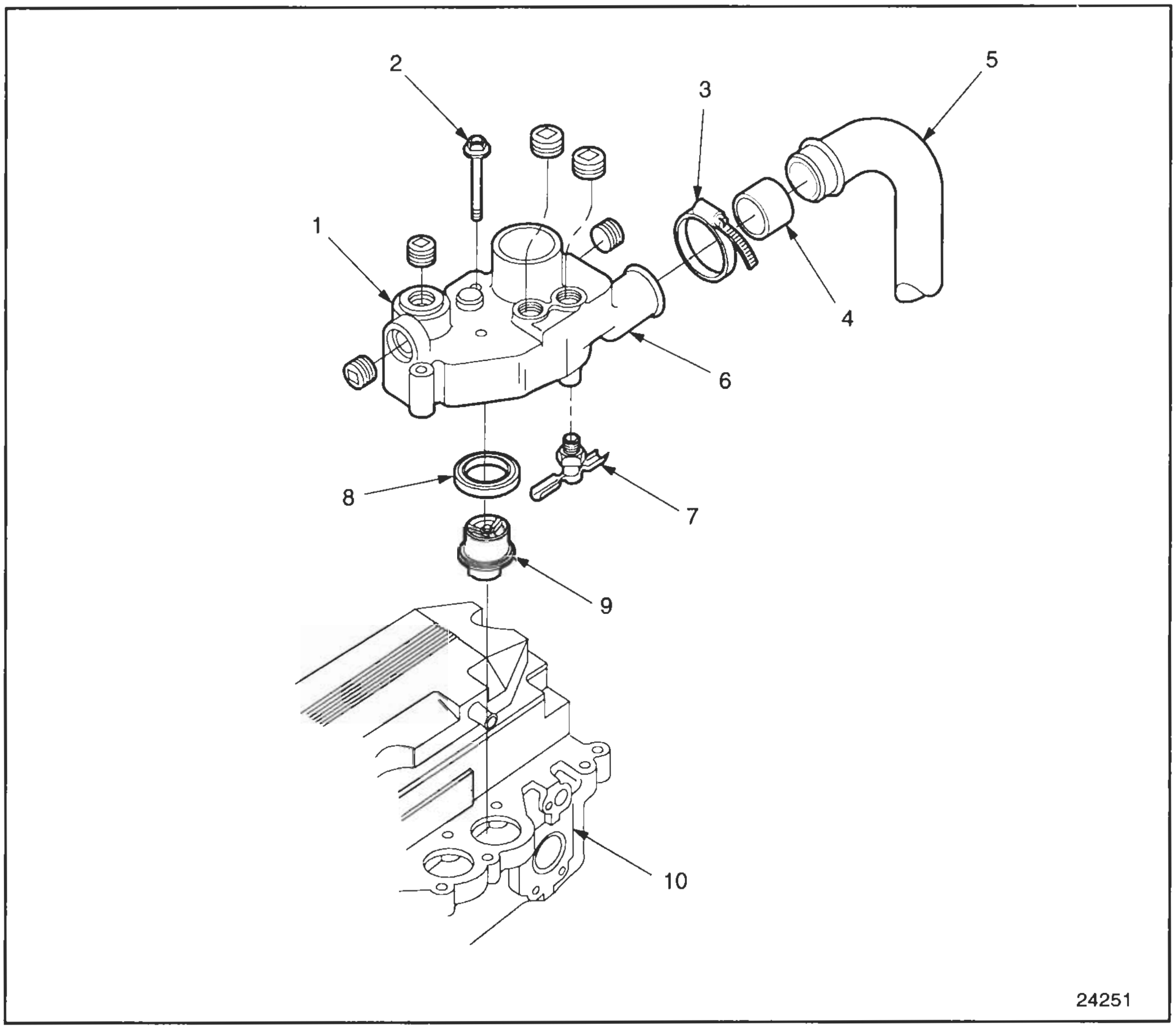
4.2.7 Installation of Water Pump

Install the water pump as follows:

1. Coat the water pump seal ring with clean engine oil.
2. Install the seal ring to the groove in the water pump housing.
3. Coat the water pump drive gear with clean engine oil.
4. Install the water pump to the engine, meshing the water pump drive gear with the bull gear.
5. Install the three water pump housing–to–gear case bolts. Tighten the bolts alternately and evenly to draw the water pump straight into the engine. Tighten the bolts to 58–73 N·m (43–54 lb·ft) torque.
6. Measure the gear backlash. Refer to section 1.21.
7. Slide the coolant hoses into position and tighten the hose clamps.
8. Refer to section 11.3.5 for verification of proper water pump installation.

4.3 THERMOSTAT

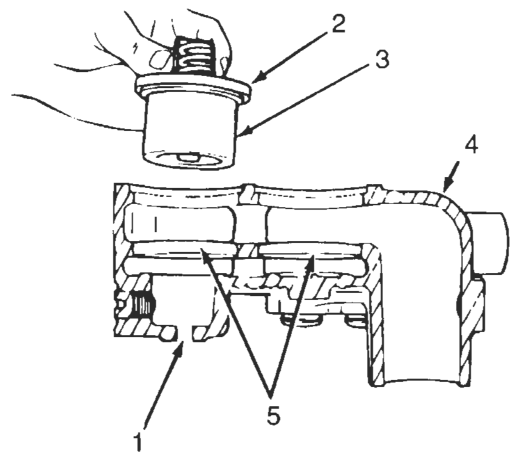
The temperature of the engine coolant is controlled by two blocking-type thermostats located in a housing attached to the right side of the cylinder head. See Figure 4-32.



1. Vent Line Connection
2. Bolts, Thermostat Housing-to-Cylinder Head (4)
3. Hose Clamps (2)
4. Hose, Coolant
5. Bypass Tube
6. Thermostat Housing
7. Drain Cock
8. Seals, Thermostat Housing (2)
9. Thermostats (2)
10. Cylinder Head

Figure 4–32 Thermostat and Related Parts

In addition to a rubber seal that is part of the thermostat, there is a lip-type seal for each thermostat that is installed in a bore in the thermostat housing. See Figure 4-33.



1. Connection Opening, Vent Line
2. Seal, Thermostat (2)
3. Thermostat (2)
4. Thermostat Housing
5. Seals, Thermostat Housing (2)

Figure 4–33 Thermostat Seals

At coolant temperatures below approximately 86–89°C (186–193°F), the thermostat valves remain closed and block the flow of coolant from the engine to the radiator. During this period, all of the coolant in the system is recirculated through the engine and is directed back to the suction side of the water pump via a bypass tube. As the coolant temperature rises above 86–89°C (186–193°F) the thermostat valves start to open, restricting the bypass system, and allowing a portion of the coolant to circulate through the radiator. When the coolant temperature reaches approximately 97°C (207°F) the thermostat valves are fully open, the bypass system is blocked off, and the coolant is directed through the radiator. See Figure 4–34.

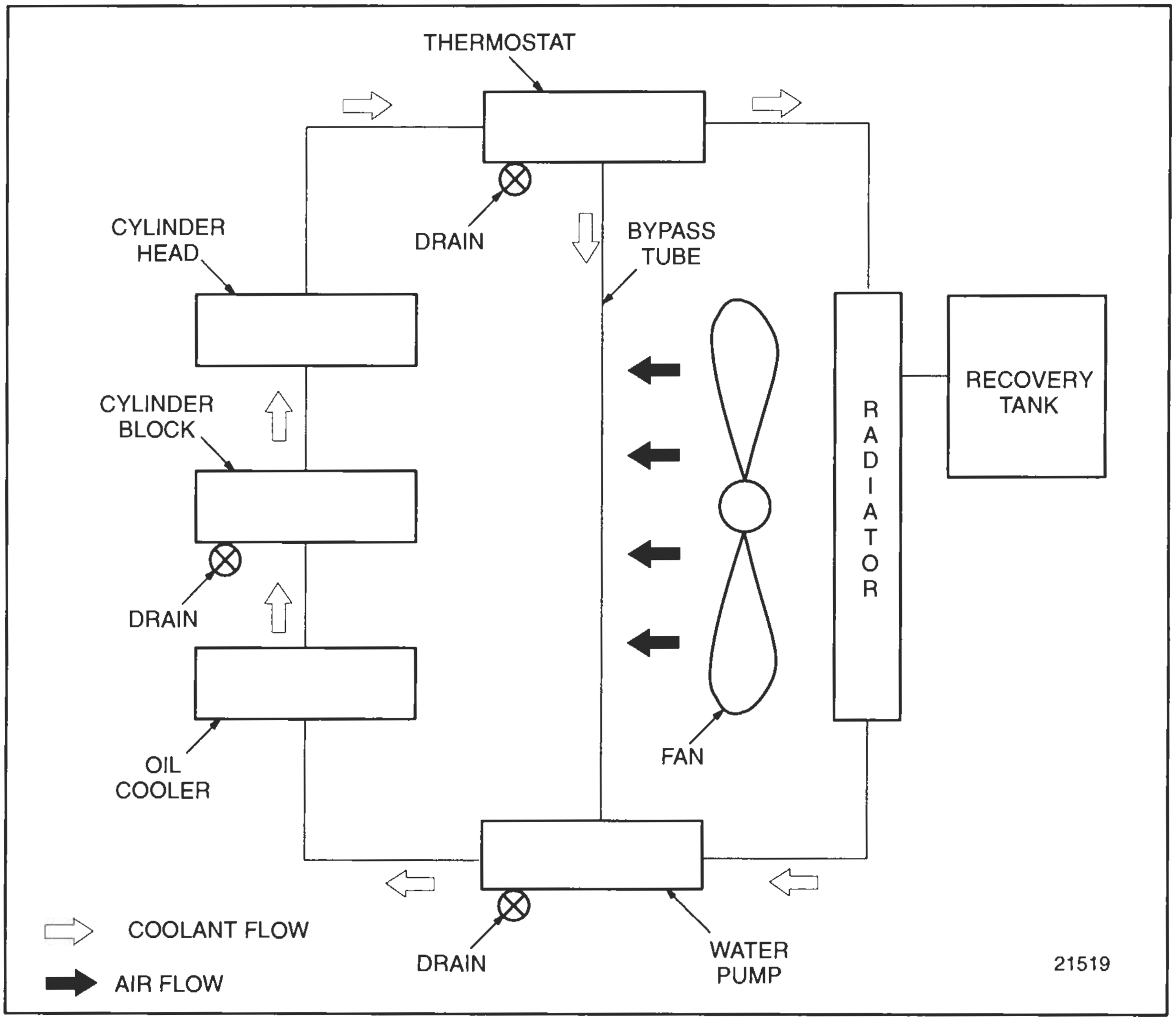


Figure 4–34 Coolant Flow Schematic

Properly operating thermostats are essential for efficient operation of the engine. If the engine operating temperature deviates from the normal range of 86–99°C (186–210°F) remove, inspect and replace the thermostats if necessary.

4.3.1 Repair or Replacement of Thermostat

To determine if repair or replacement of the thermostat is necessary, perform the following procedure. See Figure 4-35.

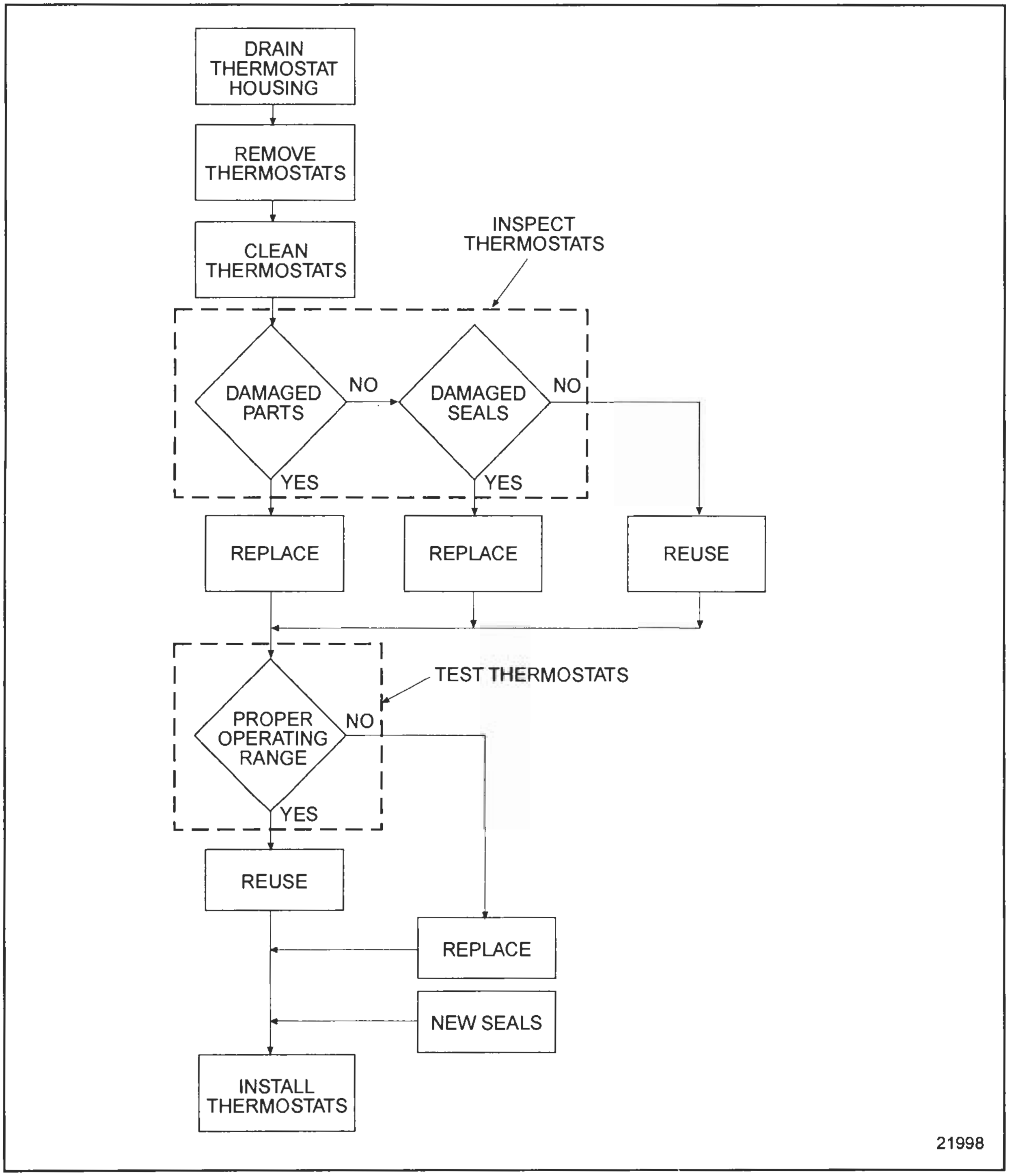


Figure 4–35 Flowchart for Repair or Replacement of Thermostat

4.3.2 Draining and Removal of Thermostat

Drain the thermostat as follows:

CAUTION:
Use extreme care when removing the coolant pressure cap. Remove the cap slowly after the engine has cooled. The sudden release of pressure from a heated cooling system can result in loss of coolant and possible personal injury (scalding) from the hot liquid.

1. Slowly open the coolant pressure control (radiator) cap.
2. Open the draincock located on the bottom of the thermostat housing.
3. Drain the cooling system so that the coolant is below the thermostat level.

Remove the thermostat as follows:

1. Loosen the hose clamps on the coolant hoses connected to the thermostat housing.
2. Slide the hoses off the housing.
3. Disconnect the vent line and any other lines which are connected to the thermostat housing.
4. Remove the four thermostat housing–to–cylinder head attaching bolts.
5. Remove the thermostat housing assembly from the engine.
6. Remove the thermostats from the thermostat housing.
7. Remove and discard the thermostat housing seals.

4.3.2.1 Inspection of Thermostat

Inspect thermostat as follows:

1. Clean all of the parts in clean fuel oil.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

2. Dry all parts with compressed air.
3. Inspect thermostat body seal for damage, cracks or nicks.
   [a] If any damage is noted, replace seal.

4.3.3 Testing Thermostat

Check the operation of a thermostat as follows:

NOTICE:
Ensure thermostat is operational. If thermostat motion becomes impaired, overheating may result. An engine which has overheated may also cause the thermostats to become inoperative. A thermostat stuck in the open position may not allow the engine to reach normal operating temperature. The incomplete combustion of fuel due to cold operation will result in build–up of carbon deposits on the pistons, rings and valves. A thermostat that does not fully open may cause engine overheating.

1. Immerse the thermostat in a metal container of water. See Figure 4–36.

Figure 4–36 Checking Thermostat Operation

2. Place a thermometer in the container using care not to allow the thermometer to touch the bottom or sides of the container.
3. While slowly agitating the water to maintain an even temperature, apply heat to the container. Allow at least 10 minutes for the thermostats to react before determining if the thermostats are opening in the correct temperature range and are fully opened at 97°C (207°F).

CAUTION:

Use caution when performing this procedure. Personal injury (scalding) may result from contact with the hot liquid.

4. As the water is heated, the thermostat should begin to open (the normal opening temperature is stamped on the thermostat). 88°C (190°F) thermostats are used on the Series 50 engine with a start–to–open temperature range of 86–89°C (186–193°F). The thermostat is fully open (9.5 mm [.375 inches]) at 97°C (207°F).
5. If thermostat does not operate properly replace.

4.3.4 Installation of Thermostat and Seal

Install new thermostat as follows:

1. Position the a new seal onto seal installer, J 8550, and handle, J 7079-2. See Figure 4-37.

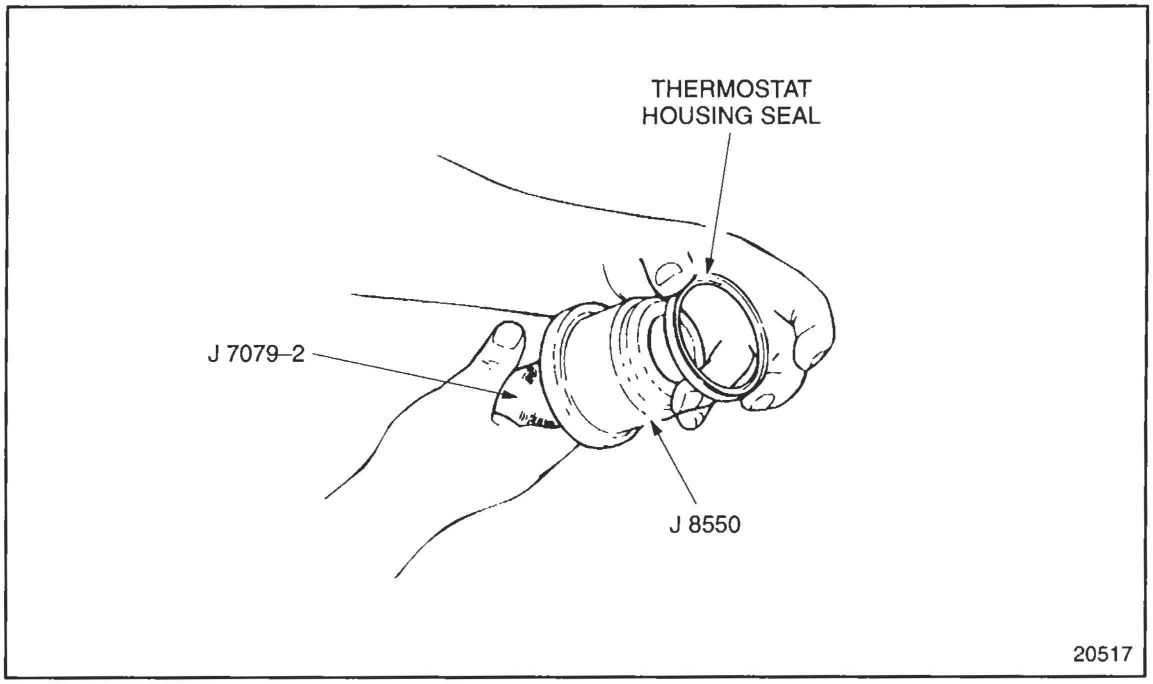


Figure 4-37 Positioning the Seal onto Seal Installer

2. Support the thermostat housing on a work bench so that it is level. See Figure 4-38.

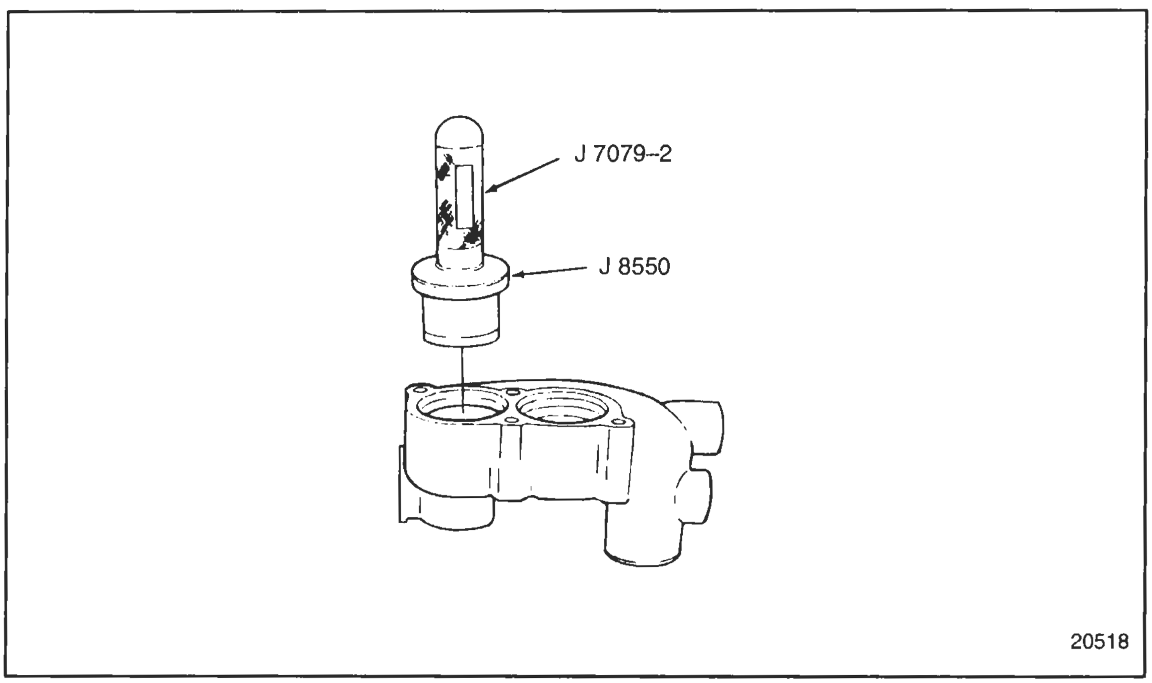


Figure 4-38 Thermostat Housing Seal Insertion

3. Insert the seal driver with seal installed, into the thermostat housing.
4. Drive the seal into the bore with a hammer, until the installation tool bottoms on the housing. See Figure 4–39. Rotate the tool during installation to ensure the seal is installed straight. Remove tools J 7079–2 and J 8550.

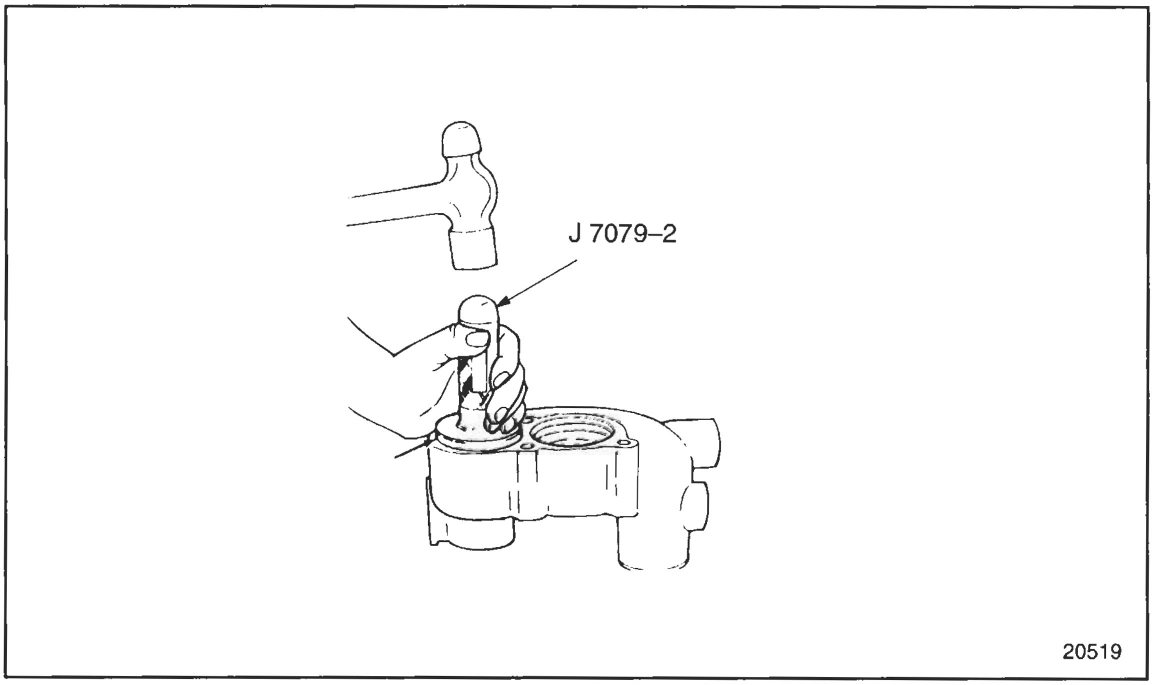


Figure 4–39 Thermostat Housing Seal Installation

5. Repeat step 1. through step 4. for the other seal.
6. Coat the lip of the seals with clean engine oil.
7. Place the thermostats, spring up, into the thermostat housing.

8. Press down on the thermostats to seat them. See Figure 4–40.

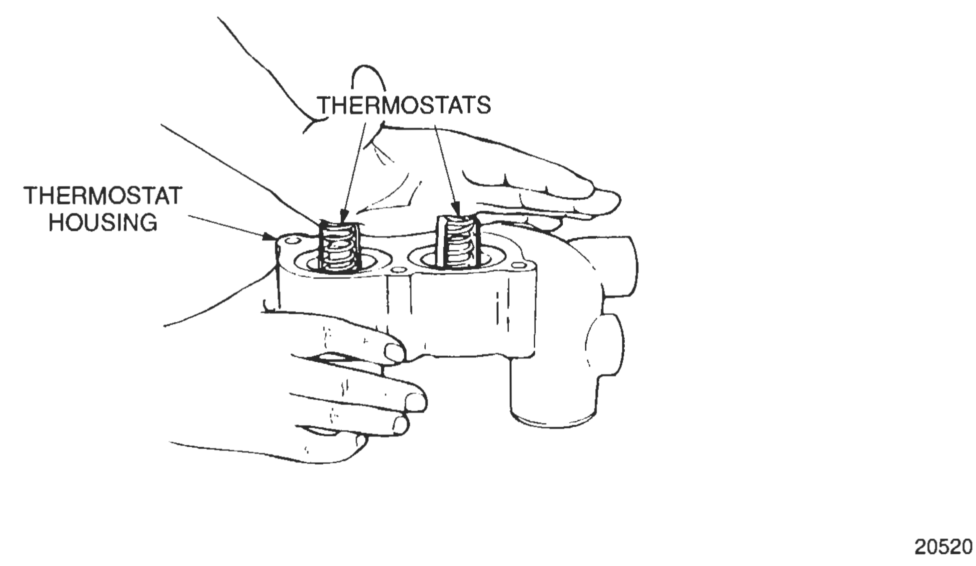


Figure 4–40 Seating Thermostats

9. Be sure the machined surface of the thermostat housing, where it contacts the cylinder head, is clean and dry.
10. Install the thermostat housing to the cylinder head with the four attaching bolts. Tighten the bolts to 58–73 N·m (43–54 lb·ft) torque.
11. Install the coolant hoses to the thermostat housing. Tighten the hose clamps.
12. Apply a coating of Loctite Pipe Sealer with Teflon, J 26558–92, or equivalent to the threads of the draincock if it was removed from the bottom of the thermostat housing.
13. Install and tighten the drain cock.
14. Install any other components removed for this operation.
15. Close the draincocks in the water pump housing and at the right rear of the cylinder block.
16. Install the thermostat housing vent line and any other lines that were removed from the housing.
17. Fill the cooling system. Refer to section 13.5.4.
18. Refer to section 11 for verification of thermostat installation. Listed in Table 11–2 are the normal cooling system operational parameters.

4.4 COOLANT PRESSURE CONTROL CAP

The radiator (or expansion tank) has a pressure control cap with a normally closed valve. The cap is designed to permit a pressure in the cooling system equal to the rating stamped on the top of the cap. A cap with a "9" on the top allows the cooling system to develop 62 kPa (9 lb/in.^{2}) before the valve opens. See Figure 4-41. This system pressure raises the boiling point of the coolant and reduces coolant loss. The maximum allowable coolant temperature, regardless of the pressure cap used, is 99°C (210°F).

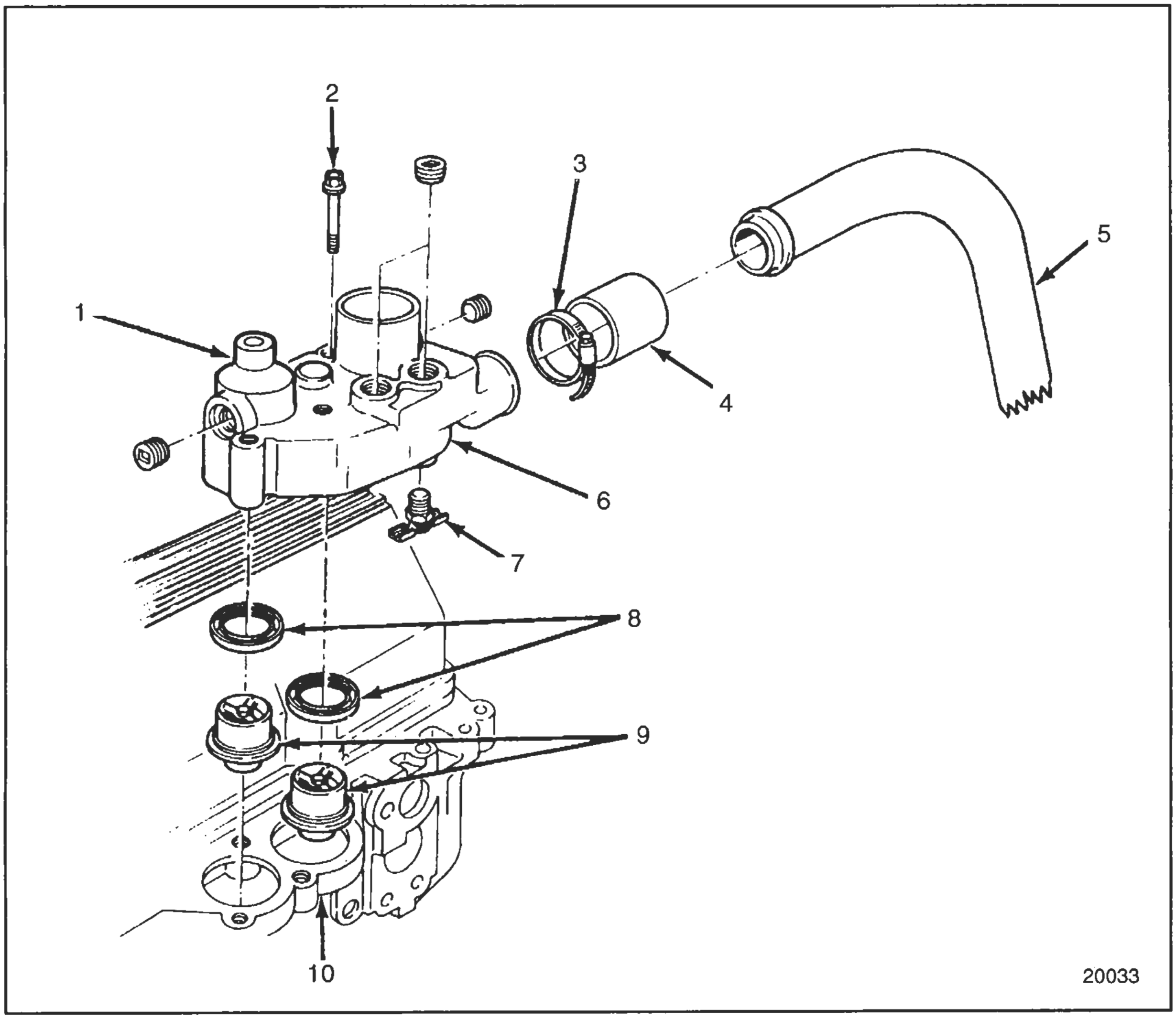


Figure 4–41 Pressure Control Cap (Pressure Valve Open)

To prevent collapse of hoses and other parts which are not internally supported, a second valve in the cap opens under vacuum when the system cools. See Figure 4–42. It also permits coolant to flow from coolant recovery bottle (when used) to the radiator tank.

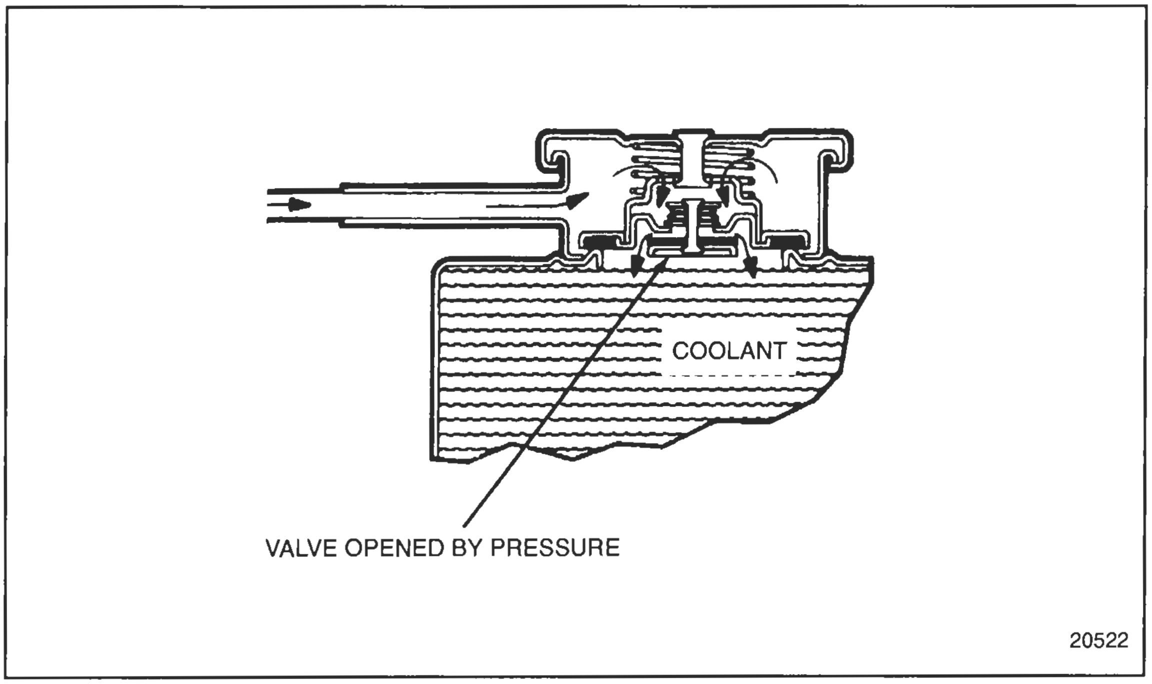


Figure 4–42 Pressure Control Cap (Vacuum Valve Open)

4.4.1 Repair or Replacement of Pressure Control Cap

Refer to the OEM guideline for pressure control cap service procedure.

4.4.2 Cleaning and Removal of Pressure Control Cap

Remove the pressure control cap as follows:

CAUTION:

Use extreme care when removing the coolant pressure control cap. Remove the cap SLOWLY after the engine has cooled. The sudden release of pressure from a heated cooling system can result in loss of coolant and possible personal injury (scalding) from the hot liquid.

1. Wipe the outside area on the pressure control cap clean before removal.
2. Push down on pressure control cap while turning counter–clockwise.

4.4.2.1 Inspection of Pressure Control Cap

Detroit Diesel does not offer pressure control (radiator) caps as original equipment on Series 50 engines.

Clean and inspect cap periodically. Check operation of both valves using test kit J 24460–01 or equivalent. Replace if necessary. Inspect and clean fill neck. Replace if damaged.

It is recommended that all Series 50 on–highway vehicle engines use a minimum 62 kPa (9 lb/in.^{2}) pressure control cap. If the pressure valve does not open between 55 kPa (8 lb/in.^{2}) and 69 kPa (10 lb/in.^{2}) or the vacuum valve does not open at 4.3 kPa (.625 lb/in.^{2}) (differential pressure), replace the pressure control cap.

4.4.3 Installation of Pressure Control Cap

Install the pressure control cap as follows:

1. Wipe area clean before installing the pressure control cap.
2. Push down on pressure control cap while turning clockwise.

4.5 ENGINE COOLING FAN

The engine cooling fan can be mounted at the front of the engine and is belt driven from the crankshaft pulley. See Figure 4-43.

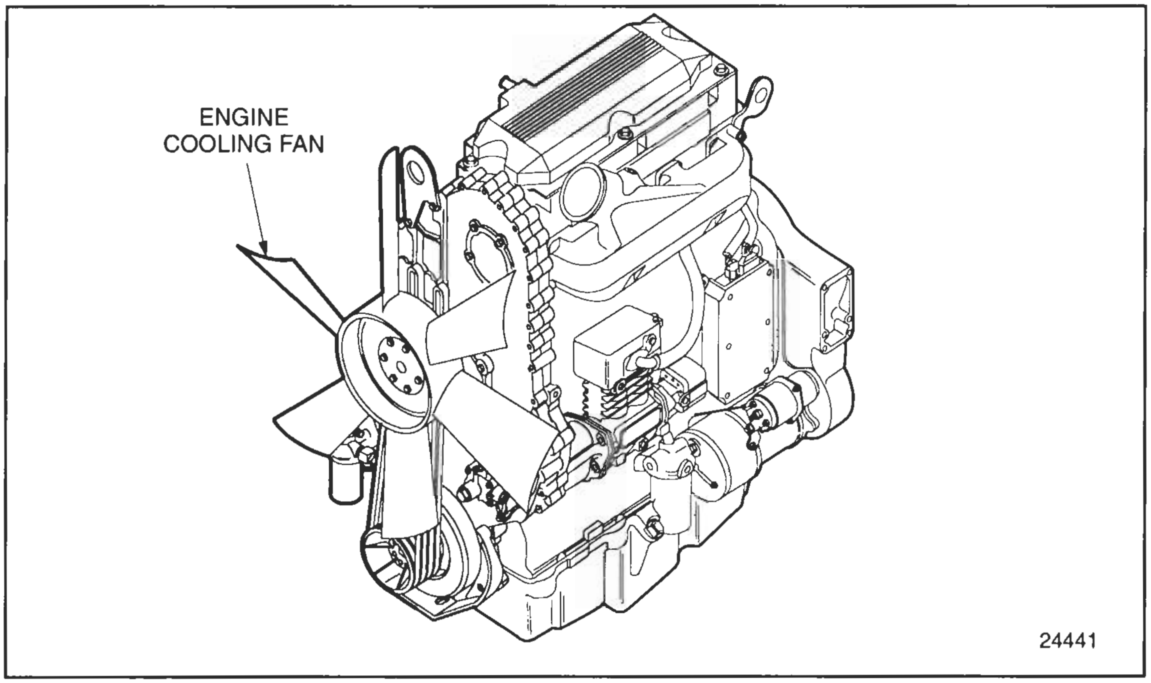
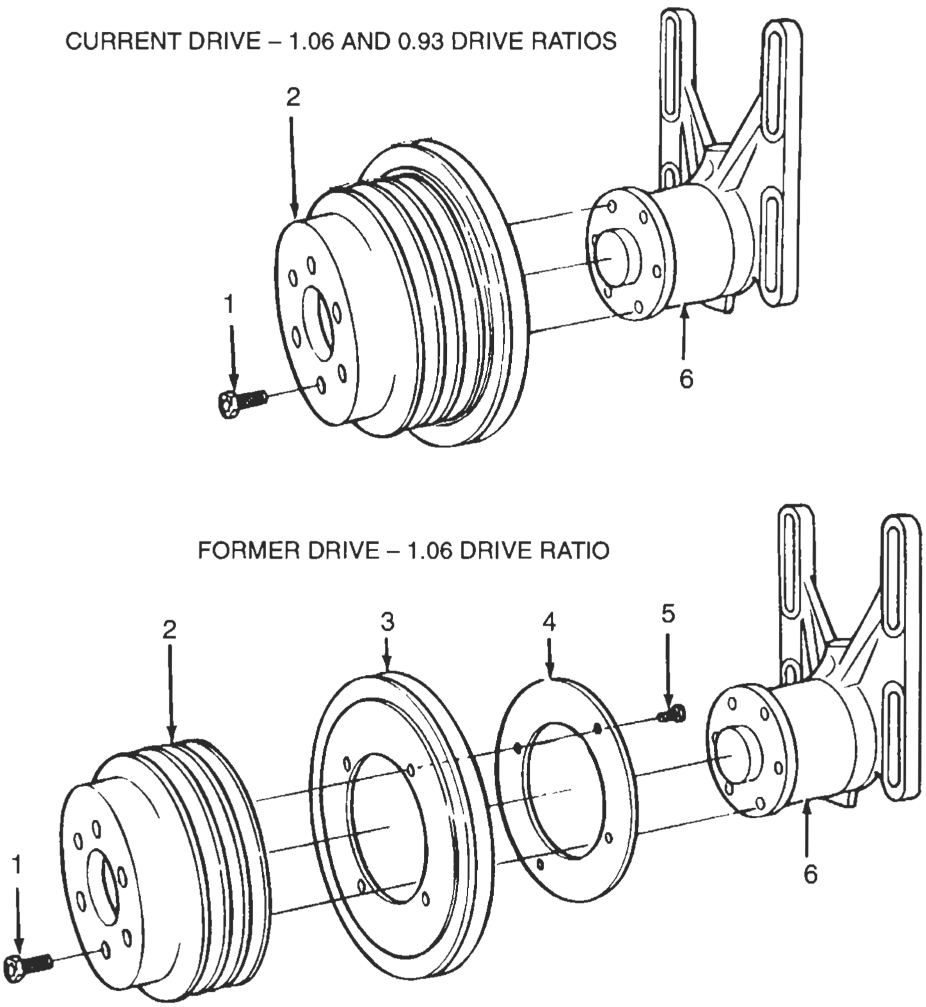


Figure 4–43 Engine Cooling Fan Location

On most applications, the fan is thermostatically controlled. This fan assembly is designed to regulate the fan speed and maintain an efficient engine coolant temperature regardless of the variations in the engine load or outside air temperature. No adjustment of the thermostatic control is necessary.

The three-groove pulley hub uses a matched set of three drive belts. On some units equipped with an air conditioning compressor, an additional pulley and retaining plate are attached to the three-groove pulley. See Figure 4-44.

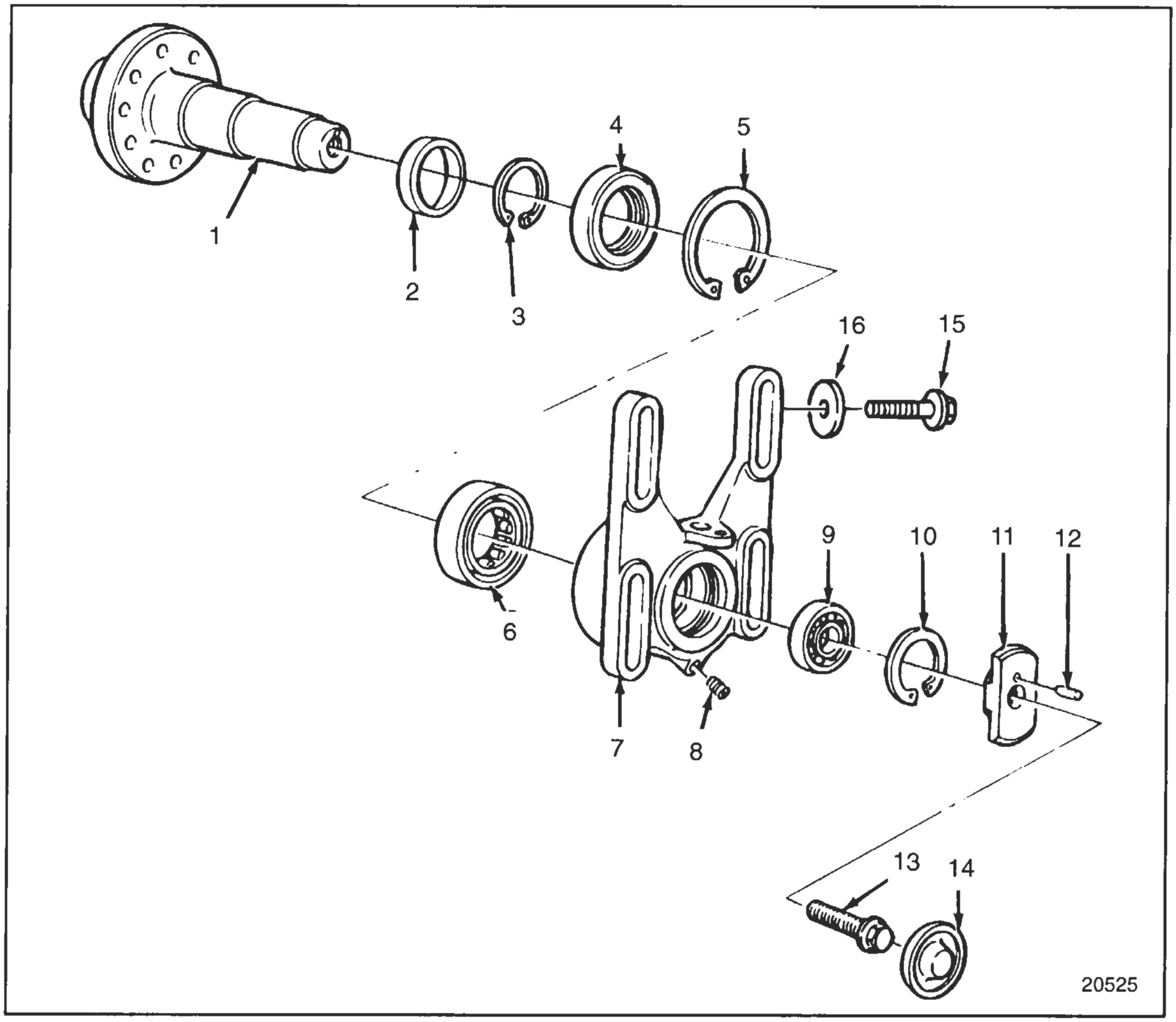


1. Bolt, Fan Retaining (6)
2. Fan Pulley
3. Drive Pulley, Air Conditioning Compressor
4. Retaining Plate
5. Bolt, Air Conditioning Retaining
6. Fan Hub Assembly

Figure 4-44 Air Conditioning Compressor Drive Pulley and Related Parts

Whenever it is necessary to replace one of the crankshaft pulley-to-fan hub drive belts, all three belts must be replaced as a matched set. Refer to section 13.5.7 for belt adjustment or replacement information.

The fan hub is supported by a front roller bearing and a rear ball bearing. Internal snap rings are used to retain the bearings in the housing and on the shaft. A single lip grease seal is mounted in the fan hub housing. A hub cap seals the bearing cavity at the rear of the housing. See Figure 4–45.



1. Drive Shaft, Fan
2. Race, Front Bearing Inner
3. Snap Ring, Inner Race Retaining
4. Grease Seal
5. Snap Ring, Front Bearing Retaining
6. Bearing, Front Roller
7. Housing, Fan Hub
8. Pipe Plug
9. Ball Bearing, Rear
10. Snap Ring, Rear Bearing Retaining
11. Spacer
12. Pin
13. Bolt, Spacer–to–drive
14. Hub Cap
15. Bolt, Fan Hub Mounting (4)
16. Hardened Washer (4)

Figure 4–45 Fan Hub and Related Parts

The fan hub utilizes four elongated mounting holes and a single threaded rod for adjustment. The fan hub is mounted to the fan support bracket with four bolts. See Figure 4–46.

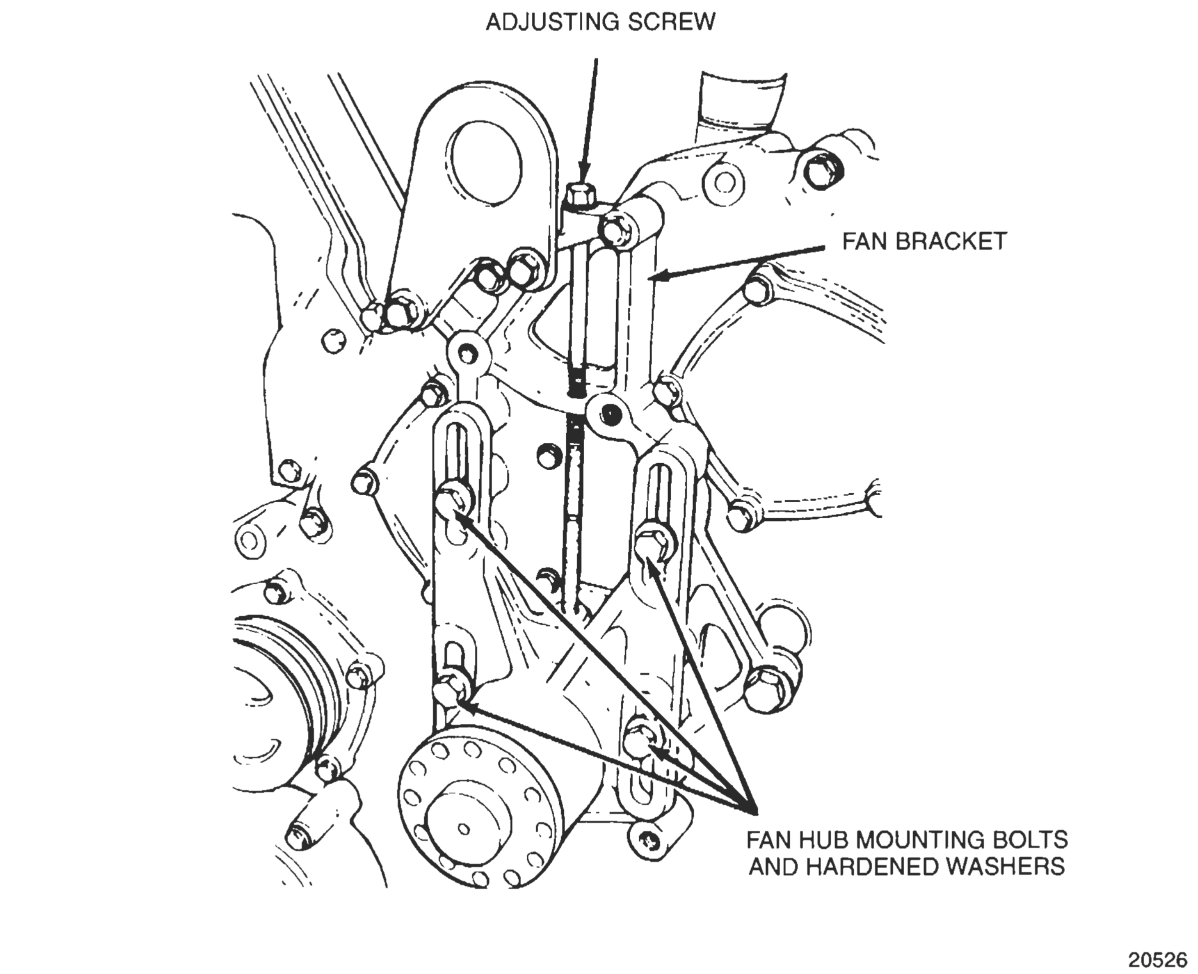


Figure 4–46 Fan Hub Mounting

The bearings and the cavity between the bearings are packed with grease at the time the fan hub is assembled. Refer to section 13.5.22 for the maintenance schedule.

4.5.1 Repair and Replacement of Engine Cooling Fan

To determine if repair is possible or replacement of the engine cooling fan is necessary preform the following procedure. See Figure 4-47.

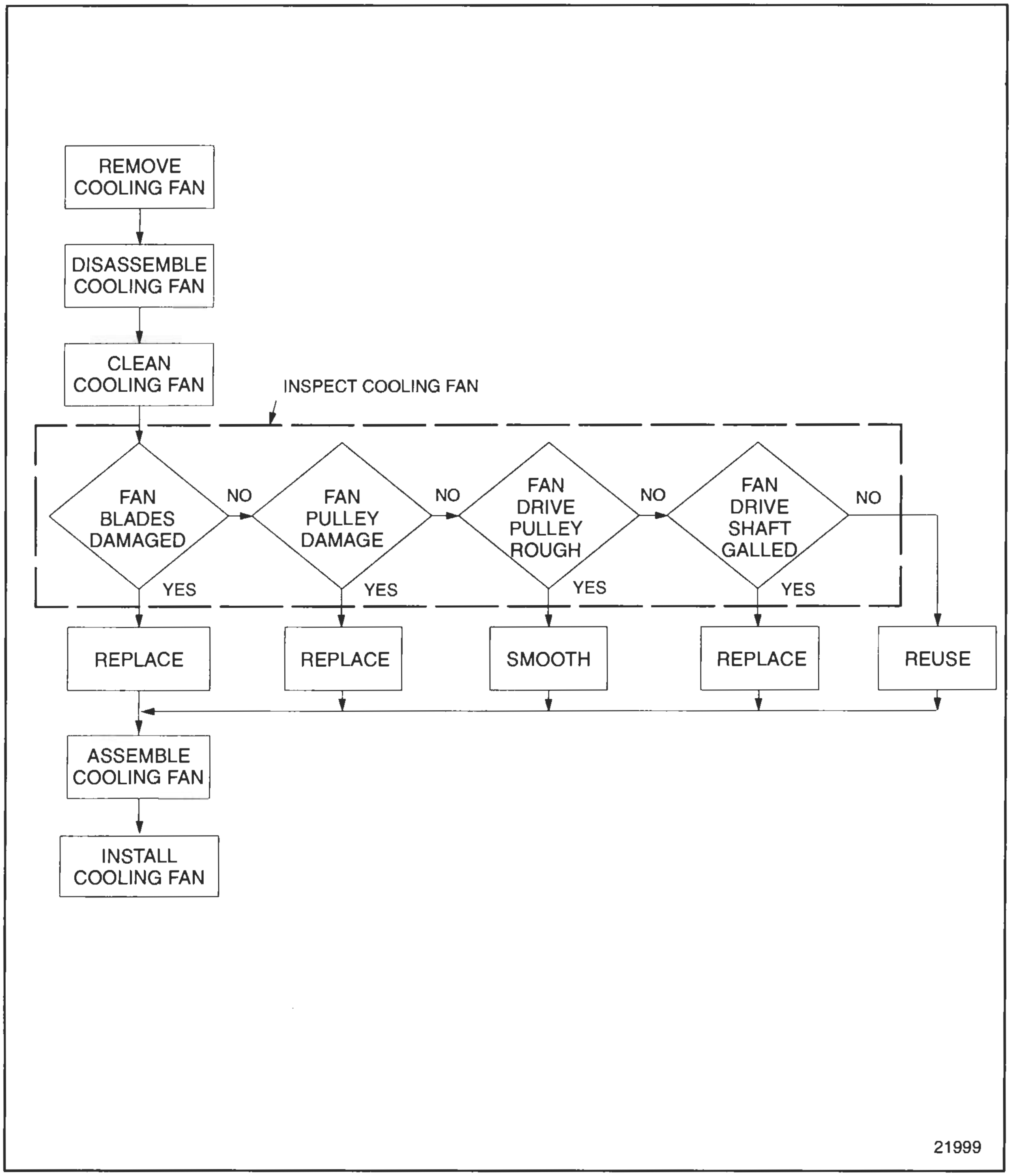


Figure 4-47 Flowchart for Repair or Replacement of Engine Cooling Fan

4.5.2 Cleaning and Removal of Engine Cooling Fan

Remove the engine cooling fan as follows:

NOTICE:
Before removing the fan, check the blades for alignment or damage. Do not rotate the fan by pulling on the fan blades. Engine damage and radiator damage could result.

The fan blades must rotate in a vertical plane parallel with and a sufficient distance from the radiator core. Cracked, deformed or otherwise damaged fan blades may reduce the efficiency of the cooling system, throw the fan out of balance, or damage the radiator cores.

1. If equipped with air conditioning, loosen the air conditioning compressor mounting bolts. Remove the compressor drive belt.
2. Loosen the four fan hub–mounting bolts. See Figure 4–46.
3. Turn the adjusting rod counterclockwise enough to allow slack in the drive belts.
4. Remove the fan attaching bolts and remove the fan, fan drive belts and fan pulley.
5. Remove the adjusting rod from the housing by unscrewing it.
6. Remove the four fan hub–mounting bolts. Remove the fan hub assembly.

4.5.3 Disassembly of Engine Cooling Fan

Disassemble the engine cooling fan as follows:

1. Remove the hub cap at the rear of the housing by piercing the cap with a punch and prying the cap out of the housing.

NOTICE:
If a vise is used to secure the fan hub, use wood or leather between hub and vise. Exercise extreme caution to prevent damage to the fan hub.

2. Secure the fan hub in a vise. Loosen and remove the bolt, securing the spacer to the shaft.
3. Remove the spacer.
4. Place the housing, fan mounting surface down, on a press bed on wood blocks high enough to allow the shaft to be removed. Press the shaft to remove it from the housing.

CAUTION:
Due to the size and tension of the snap ring, use snap ring pliers of a type to ensure maximum safety whenever removing or installing the water pump cover snap ring. Wear adequate eye protection, and press a hammer against the pump cover to help prevent personal injury, should the snap ring slip off the pliers.

5. Remove the roller bearing inner race snap ring from the shaft using snap ring pliers.
6. Remove the roller bearing inner race using a two–jaw puller.

NOTE:
Any time the shaft is removed from the housing, the ball bearing assembly (rear bearing) must be replaced. Any time the roller bearing inner race is removed from the shaft or the roller bearing assembly is removed from the housing, the roller bearing assembly must be replaced.

7. Remove the grease seal from the housing and discard the seal.
8. Remove the bearings from the housing as follows:
   [a] Remove the rear ball bearing snap ring using snap ring pliers.
   [b] Support the housing, fan side up, on two wood blocks spaced far enough apart to permit removal of the rear bearing from the housing.
   [c] Remove the bearing from the housing by tapping alternately around the rear face of the bearing outer race with a small brass rod and hammer.
   [d] Reverse the housing on the wood blocks. Remove the front bearing snap ring using snap ring pliers.
   [e] Remove the front bearing from the hub in the same manner as the rear bearing. Refer to step [a] through step [d].

4.5.3.1 Inspection of Engine Cooling Fan

Inspect the engine cooling fan as follows:

1. Clean the fan, fan hub and related parts with clean fuel oil.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

2. Dry the fan, fan hub and related parts with compressed air.
3. Check the fan blades for cracks or other damage.
4. Replace the fan if the blades are cracked or deformed.
5. Inspect fan pulley for wear or damage to grooves.
   [a] If fan pulley grooves are damaged or severely worn, replace the pulley.
6. Inspect fan pulley for rust or rough spots.
7. Remove any rust or rough spots in the grooves of the fan pulley.
8. Inspect the fan drive shaft for galling, pitting, scoring or cracks.
9. Replace as necessary. Small imperfections in the bearing contact surfaces may be removed using crocus cloth wet with fuel oil.

4.5.4 Assembly of Engine Cooling Fan

Assemble the engine cooling fan as follows:

1. Install the roller bearing inner race to the fan hub shaft. Support the shaft (fan side down) on a press bed. Use tool, J 36310-4, part of tool set J 36310-A, to press the race on the shaft firmly against the shoulder. See Figure 4-52.

NOTE:
The identification number side of the race should be against the tool.

CAUTION:
Due to the size and tension of the snap ring, use snap ring pliers of a type to ensure maximum safety whenever removing or installing the water pump cover snap ring. Wear adequate eye protection, and press a hammer against the pump cover to help prevent personal injury, should the snap ring slip off the pliers.

2. Using snap ring pliers, install the inner race retaining snap ring on the shaft.

NOTE:
Be sure the snap ring is fully seated in the groove.

3. Using Texaco Premium RB or equivalent lithium base multipurpose grease, pack the roller bearing.
4. With the fan drive housing on a press bed (fan side up) install the roller bearing into the housing. Using the stepped side of tool, J 36310-2, part of tool set J 36310-A, press the bearing firmly against the shoulder in the housing.
5. Install the roller bearing retaining snap ring.

NOTE:
Be sure the snap ring is fully seated in the groove in the housing.

NOTICE:
Care must be taken to only apply enough pressure to seat the seal against the snap ring. Excess pressure will deform the seal case.

6. Using the opposite (smooth side) of tool J 36310-2, part of tool set J 36310-A, press the oil seal into the housing against the snap ring.

7. Using Texaco Premium RB or equivalent lithium base multipurpose grease, pack the ball bearing.
8. Using the wider end of tool J 36310–1, part of tool set J 36310–A, to press on the outer race of the bearing, turn the fan hub housing over (fan side down) on the press bed and install the ball bearing assembly into the housing.
9. Press the bearing firmly against the shoulder in the housing.
10. Install the ball bearing retaining snap ring in the housing.

NOTE:
Be sure the snap ring is fully seated in the groove.

11. Pack the housing with Texaco Premium RB or equivalent lithium base multipurpose grease. Do not overfill the housing.

NOTE:
The housing should be between 1/2 to 2/3 full.

12. Coat the lip of the new oil seal with clean engine oil.
13. With the fan hub shaft (fan side down) supported on a press bed, carefully install the housing over the shaft.
14. Using the narrow end of tool J 36310–1, part of tool set J 36310–A, press the inner race of the ball bearing onto the shaft until it is firmly seated against the shoulder on the shaft.

NOTICE:
If a vise is used to secure the water pump drive gear for locknut or impeller removal, use soft jaws on the vise and exercise extreme caution to prevent damage to the water pump drive gear teeth.

15. Secure the fan hub shaft in a vice with soft (brass) jaws.
16. Index the locating pin in the shaft with its mating hole in the spacer and install the spacer.
17. Install the spacer retaining bolt and torque to 58–73 N·m (43–54 lb·ft).
18. Coat the edge of the hub cap with a sealant such as Loctite 620 or equivalent.
19. Install the cap into the end of the housing.
20. Using the flat side of tool J 36310–2, part of tool set J 36310–A, press the cap into the housing.

NOTE:
The raised center section of the cap should be flush with the surface of the housing.

4.5.5 Installation of the Engine Cooling Fan

Install the engine cooling fan as follows:

1. Install the fan hub assembly to the support bracket using the four bolts and hardened washers. Do not tighten the bolts.
2. Install the adjusting rod in the housing.
3. If removed, install the air conditioning compressor drive pulley and retaining plate to the fan drive pulley. Tighten the retaining bolts to 30–38 N·m (22–28 lb·ft) torque.
4. Install the fan drive pulley on the fan hub assembly.
5. Install the fan to the fan drive pulley. Align the holes in the fan, drive pulley and drive shaft.
6. Install the attaching bolts through the fan and pulley and thread them into the tapped holes in the fan hub. Tighten the bolts in a crisscross pattern to 47–53 N·m (35–39 lb·ft).
7. Install the drive belts to the fan pulley and crankshaft pulley.
8. Adjust the drive belts to provide the proper tension.
   Refer to section 13.5.7.
9. Tighten the fan hub–mounting bolts to 101–126 N·m (75–93 lb·ft) torque.

4.6 COOLANT FILTER AND CONDITIONER

The engine cooling system filter and conditioner is a compact bypass type unit with a replaceable spin-on type element. See Figure 4-48. The factory installed coolant filter is mounted on the gear case cover.

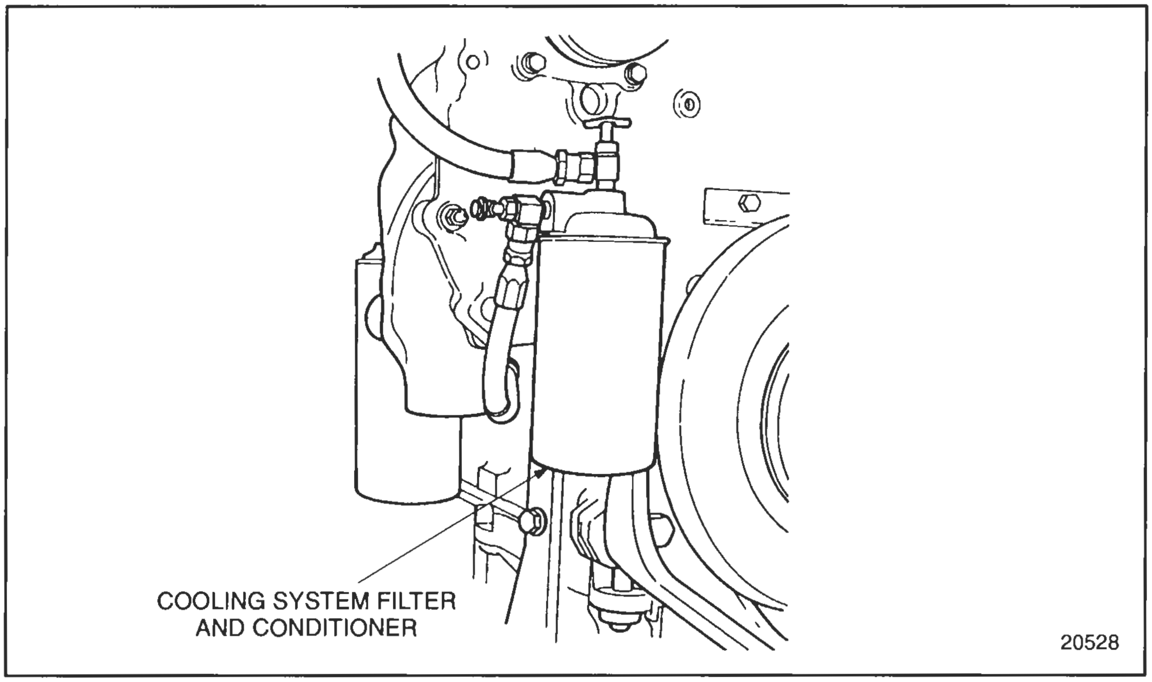


Figure 4-48 Coolant Filter

A correctly installed and properly maintained coolant filter and conditioner provides a cleaner engine cooling system, greater heat dissipation, increased engine efficiency through improved heat conductivity and contributes to longer life of engine parts.

The filter provides mechanical filtration by means of a closely packed element through which the coolant passes. Any impurities such as sand and rust particles suspended in the cooling system will be removed by the straining action of the element. The removal of these impurities will contribute to longer water pump life and proper operation of the thermostat.

The filter also serves to condition the coolant by softening the water to minimize scale deposits, maintain an acid-free condition and act as a rust preventive.

Corrosion inhibitors are placed in the element and dissolve into the coolant, forming a protective rustproof film on all of the metal surfaces of the cooling system. Refer to section 5.3.3.

4.6.1 Repair or Replacement of Coolant Filter and Conditioner

Replace filters at recommended scheduled maintenance intervals.
Refer to section 13.5.12.

4.6.2 Installation of Coolant Filter and Conditioner

Refer to section 13.5.12 for coolant filter and conditioner replacement procedure.

4.7 RADIATOR

The radiator is an OEM supplied component. Follow OEM guidelines.

4.7.1 Repair or Replacement of Radiator

Perform the following steps to reverse flush the radiator:

1. Remove scale in cooling system by using a descaling solvent. Follow manufacture instructions.
2. Neutralize the system with a neutralizing agent. Follow manufacture instructions.
3. Drain the cooling system. Refer to section 13.5.4.
4. Remove the radiator inlet and outlet hoses.
5. Remove the water pump inlet and outlet hoses.
6. Attach a hose to the top of the radiator to lead water away from the engine.
7. Attach a hose at the bottom of the radiator and insert a flushing gun in the hose.
8. Connect the water hose of the gun to the water outlet and the air hose to the compressed air outlet.

NOTICE:
Apply air gradually. Do not exert more than 138 kPa (20 lb/in.^{2}) air pressure. Too great a pressure may rupture a radiator tube.

9. Turn on the water and when the radiator is full, turn on the air in short blasts, allowing the radiator to fill between blasts.
10. Continue flushing until only clean water is expelled from the radiator.
11. Remove flushing gun and hoses from radiator.
12. Attach the water pump inlet and outlet hoses.
13. Attach the radiator inlet and outlet hoses.
14. Fill cooling system. Refer to section 13.5.4.
15. Refer to section 11.3.5 for verification of proper radiator installation.

4.A ADDITIONAL INFORMATION

Description **Page**

SPECIFICATIONS

This section contains the exceptions to the fastener torque specifications.

Torque Specification Exceptions – Fasteners

The proper bolt and nut torque is dependent on its size. The proper torque for metric nuts and bolts are listed in Table 6 in the "General Information" section at the beginning of this manual. The exceptions to this rule are listed in Table 4–1. Standard (nonmetric) nut and bolt torque specifications are listed in Table 5 in the "General Information" section at the beginning of this manual.

EXCEPTIONS TO STANDARD FASTENER TORQUE SPECIFICATIONS

Bolt and Size, mm	Torque, N·m	Torque, lb·ft
M24 X 1.0	203–230	150–170

TABLE 4–1 Exceptions – Metric Fastener Torque Specifications

NOTE:
The water pump drive gear retaining nut is M24 X 1.0.

SERVICE TOOLS

Listed in Table 4-2 are the service tools used in this section.

Tool Number	Tool Name
J 22380	Internal Snap Ring Pliers
J 24460–01	Cooling System Pressure Tester Kit
J 26558–92	Loctite Pipe Sealer with Teflon
J 35517–1	Water Pump Seal Installer
J 35687	Impeller and Gear Lash Tester
J 35988–B	Water Pump Service Tool Kit
J 35988–1	Oil Seal and Bearing Installer
J 35988–2	Fixture
J 35988–3A	Water Pump Service Tool
J 35988–14	Water Pump Service Tool
J 35988–18	Water Pump Service Tool
J 36310–A	Air Compressor Drive/Fan Hub Service Set
J 36310–1	Ball Bearing Remover/Installer
J 36310–2	Roller Bearing Installer
J 36310–4	Bearing Race Installer
J 7079–2	Driver Handle
J 8550	Thermostat Housing Seal Installer

Table 4–2 Service Tools

5 FUEL, LUBRICATING OIL, AND COOLANT

5.1 FUEL

The quality of fuel used is a very important factor in obtaining satisfactory engine performance, long engine life, and acceptable exhaust emission levels. The Series 50 engine was designed to operate on most diesel fuels marketed today. In general, fuels meeting the properties of ASTM Designation D 975 (Grades 1D and 2D) have provided satisfactory performance. The ASTM D 975 specification however, does not in itself adequately define the fuel characteristics necessary to assure fuel quality. The properties listed in Table 5-1, Fuel Selection Chart, have provided optimum engine performance.

General Fuel Classification	ASTM Test	No. 1 ASTM 1-D	No. 2 ASTM 2-D
Gravity, °API (Not Specified in ASTM D 975)	D 287	40-44	33-37
Flash Point, Minimum- °C (°F)	D 93	38 (100)	52 (125)
Viscosity, Kinematic-cSt @ 40°C (100°F)	D 445	1.3-2.4	1.9-4.1
Cloud Point (Not Specified in ASTM D 975)	D 2500	See Note	See Note
Sulfur Content, Maximum-wt%	D 129	0.05* (0.5†)	0.05* (0.5†)
Carbon Residue on 10%, Maximum-wt%,	D 524	0.15	0.35
Accelerated Stability, Total Insolubles, Maximum-mg/100 mL	D 2274	1.5	1.5
Ash, Maximum-wt%	D 482	0.01	0.01
Cetane Number, Minimum (Differs from ASTM D 975)	D 613	45	45
Distillation Temperature, °C (°F)	ASTM Test	No. 1 ASTM 1-D	No. 2 ASTM 2-D
IBP, Typical (Not Specified in ASTM D 975)	D 86	177 (350)	191 (375)
10% Typical (Not Specified in ASTM D 975)	D 86	196 (385)	221 (430)
50% Typical (Not Specified in ASTM D 975)	D 86	218 (425)	256 (510)
90% Maximum (Differs from ASTM D 975)	D 86	260 (500)	329 (625)
End Point, Maximum (Not Specified in ASTM D 975)	D 86	288 (550)	357 (675)
Water & Sediment, Maximum wt%	D 1796	0.05	0.05

* U.S. on-highway requirement

† Nondomestic and off-highway applications only

Note: The cloud point should be 6°C (10°F) below the lowest expected fuel temperature to prevent clogging of fuel filters by crystals.

Table 5-1 Fuel Selection Chart

NOTE:
When prolonged idling periods or cold weather conditions below 0°C (32°F) are encountered, the use of 1–D fuel is recommended. Number 1–D fuels should also be considered when operating continuously at altitudes above 5,000 ft (1,525 m).

The fuels used must be clean, completely distilled, stable, and non–corrosive. A reputable fuel supplier is the only one who can assure that the fuel you receive meets the property limits shown in the fuel selection chart. For more information regarding the significance of these properties and selection of the proper fuel, refer to DDC publication 7SE270, *Lubricating Oils, Fuel Oils and Filter Recommendations*, available from your DDC dealer or distributor.

5.1.1 Fuel Sulfur Content

The sulfur content of the fuel should be as low as possible to avoid premature wear of piston rings and liner, excessive deposit formation and minimize sulfur dioxide exhausted into the atmosphere. Limited amounts can be tolerated, but the amount of sulfur in the fuel and engine operating conditions can influence corrosion and deposit formation tendencies. The use of fuel containing greater than 0.5% sulfur will require more frequent oil changes.

NOTE:
Environmental Protection Agency (EPA) has mandated that all 1994 model year on–highway diesel engines manufactured for use in the United States must meet a new reduced exhaust particulate content of 0.10 g/hp·hr.

To meet this requirement, all diesel fuel sold in the United States for on–highway use will be limited to 0.05% maximum sulfur content. The sulfur content of diesel fuel for off–highway use will continue to be specified at 0.5% maximum. Off–highway fuel will be dyed blue for identification.

Although some concern has been expressed regarding increased piston deposits, loss of fuel lubricity, and increased soot in the engine when using low sulfur fuel, these concerns have not been seen in Detroit Diesel engines.

NOTE:
Fuel additives are not needed when burning low sulfur fuel.

Using low sulfur fuel in pre–1994 Detroit Diesel engines has no effect on maintenance or durability. In fact, these engines will also have cleaner exhaust emissions when burning this fuel.

The use of low sulfur diesel fuel does not permit extension of engine lubricating oil drain and filter change intervals. Although burning low sulfur fuel produces lower combustion acids, other contaminants (soot, water, fuel, etc.) build up at the same rates as before. In addition, the additives in the engine oil degrade at the same rates, regardless of the sulfur content.

5.1.2 Fuel Cleanliness

Fuel should be clean and free of contamination. Storage tanks and stored fuel should be inspected regularly for dirt, water, or water–emulsion sludge, and cleaned if contaminated. Storage instability of the fuel can lead to the formation of varnish or sludge in the tank. The presence of these contaminants from storage instability must be resolved with the fuel supplier. If fuel is stored on site, the following is recommended:

NOTICE:
Do not use a fuel storage tank or lines made from galvanized steel. The fuel will react chemically with the galvanized coating to form powdery flakes that will quickly clog fuel filters and cause damage to the fuel pump and injectors.

1. Keep the storage tank filler cap covered to prevent contamination by rain water.
2. Keep the tank clean, especially around the filler cap and tap areas.
3. Position the tank so that it tilts slightly toward the bottom drain. This will make it easier to drain accumulated water and sediment.
4. Minimize condensation by keeping the tank reasonably full at all times.
5. After filling the fuel storage tank, wait a few hours before filling equipment tanks. This will allow contaminants to settle.

5.1.3 Cold Weather Operation

In cold weather, diesel fuel will form wax crystals that can restrict flow and clog filters. Fuel suppliers approach this problem several ways. Some provide a specially refined product while others may use flow improving additives or winter blends. Winter blended fuel will likely contain kerosene or 1–D fuel which provide good cloud point temperatures but will result in a lighter fuel with a lower heat content. The use of such fuels is acceptable but may result in reduced engine power and/or fuel mileage.

5.1.4 Using Drained Lubricating Oil in Diesel Fuel

The disposal of waste oil is a serious environmental concern, best addressed by the engine oil supplier, who should accept responsibility for proper disposal of this material as part of the business of providing lubricant.

NOTICE:
Detroit Diesel does NOT recommend blending engine drain oil into diesel fuel. Such practice will adversely effect exhaust emissions, and will likely result in damage to the fuel injection system and the formation of excessive combustion deposits.

Detroit Diesel will not be responsible for any detrimental effects that it determines result from this practice.

5.2 LUBRICATING OIL

The selection of the proper lubricating oil is important for achieving the long and trouble-free service Detroit Diesel Series 50 engines are designed to provide. Only oils displaying the American Petroleum Institute (API) Symbol shown below are recommended. This symbol assures that the lubricant meets the minimum performance levels necessary for proper engine performance and durability.

5.2.1 Recommended Lubricant

The only type of engine oil recommended for Detroit Diesel Series 50 engines is listed in Table 5-2. Lubricants meeting these criteria have provided maximum engine life when used in conjunction with recommended oil drain and filter maintenance schedules. The API symbol for this is shown in the next illustration. See Figure 5-1.

Specification	Recommendation
SAE Viscosity Grade	15W–40
API Classification	CG–4*
HT/HS Viscosity	3.7 cP (minimum)

* CF–4 may be used until CG–4 products become available.

Table 5–2 Recommended Engine Oil

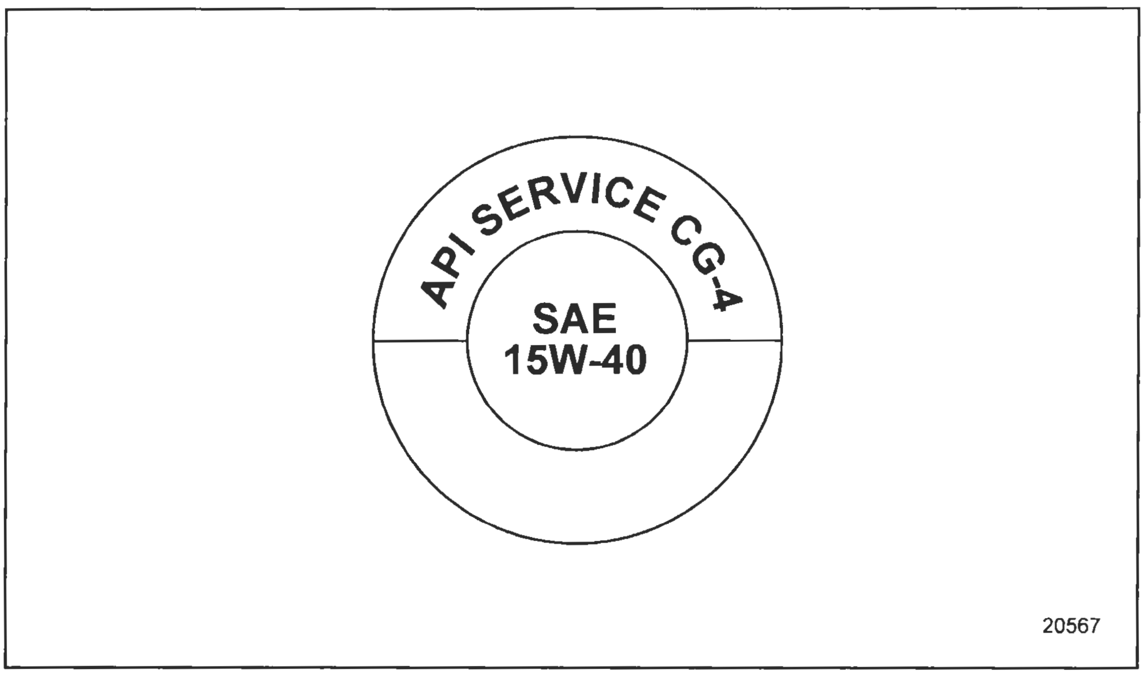


Figure 5–1 API Symbol

API Performance Category CG-4 represents a lubricant developed for on-highway, emission controlled engines operating on low sulfur fuel in applications where API CF-4 lubricants were formerly used.

NOTE:
CF–4 lubricants had an enhanced level of lubricant performance over the CE category that it replaced. Introduction of lubricants meeting the current performance level occurred in 1995.

In addition to the CG–4 nomenclature, other letters may also be present in the API Symbol, such as SF, SG, CD, CD–II, etc. These lubricants may be used provided CG–4 is included, and the lubricant meets DDC's additional requirements outlined in the following section. Refer to section 5.2.1.1.

5.2.1.1 Additional Requirements

Although the API designation identifies the minimum desirable performance levels, Detroit Diesel has identified additional properties that further assure the best possible lubricating for Series 50 engines.

- HT/HS: High Temperature/High Shear Rate Viscosity is a laboratory test measuring oil viscosity under stress induced by speed, load, and temperature. Engine manufacturers believe that HT/HS viscosity predicts oil performance in actual engine operation. The test is performed by ASTM Test Method D 4741, and the value represents the anticipated viscosity of an SAE 40 oil under those conditions.

For more information on lubricating oil selection, refer to DDC publication 7SE270, *Lubricating Oils, Fuel Oils, and Filter Recommendation*, available from your DDC dealer or distributor.

Oils meeting the new CG–4 classification were developed for on-highway, emission–controlled engines operating on low sulfur fuel in applications where API CF–4 lubricants were formerly used. To conform with this API licensing change, Detroit Diesel now recommends the use of CG–4 oils in Series 50 engines and in all other DDC four–cycle products.

NOTICE:
To avoid possible engine damage, do not use single grade (monograde) lubricants in Detroit Diesel four–cycle Series 50 engines, regardless of API classification.

The recommended viscosity grade continues to be 15W–40.

The phase–in of API CG–4 oils will not be immediate. Therefore, API CF–4 lubricants may continue to be used until CG–4 products become available. The use of CG–4 oils does not permit extension of oil drain intervals. Required oil drain and filter change intervals *must* be strictly observed when using either CG–4 or CF–4 lubricants.

For oil drain intervals and additional information on lubricating oils, refer to publication 7SE270, *Engine Requirements: Lubricating Oil, Fuel, and Filters,* available from authorized Detroit Diesel Distributors.

5.2.2 Oil Change Interval

The length of time an engine may operate before changing oil depends on the lubricant and fuel used, engine oil consumption, and operating cycle. The maximum interval the engine may operate before changing oil is listed in Table 5–3. Oil analysis may be used to determine whether this interval should be shorter, but should not be used to lengthen the interval.

Application	Oil Drain Schedule
Highway Truck and Motor Coach	15,000 miles (24,000 km)
City Coach	6,000 miles (9,600 km)
Industrial, G Drive and Agricultural	150 hours

Table 5–3 Maximum Oil Drain Intervals (Fuel Sulfur Content Less than 0.5%)

NOTE:
The use of fuels with sulfur content above 0.5% will require a shorter drain interval, and/or the use of a higher Total Base Number (TBN) oil. Refer to DDC Publication 7SE270, *Lubricating Oils, Fuel Oil, and Filter Recommendation*, for details.

5.2.3 Statement of Policy on Supplemental Fuel and Lubricant Additives

The Series 50 engine will operate satisfactorily on the commercial fuels and lubricants of good quality regularly provided by the petroleum industry through retail outlets.

Supplementary additives include all products marketed as fuel conditioner, smoke suppressants, masking agents, deodorants, tune–up compounds, top oils, break–in oils, graphitizers, and friction–reducing compounds. The regular and continued use of supplementary additives in fuels and lubricants is not recommended.

NOTE:
DDC is not responsible for the cost of maintenance or repairs due to lack of required maintenance services performance or the failure to use fuel, oil, lubricants and coolant meeting DDC–recommended specifications. Performance of required maintenance and use of proper fuel, oil, lubricants and coolant are the responsibility of the owner. See the OEM's guidelines for details.

5.2.4 Filter Selection and Change Intervals for Series 50

The oil and fuel filters recommended for use on the Series 50 engine are as follows:

- Engine Oil:
  - Full Flow–PF 2100
- Fuel Oil:
  - Primary–(AC) T 915D
  - Primary w/Separator – 023512317 (1 in.–12 adaptor thread)
  - Primary w/Separator – 023516189 (1 in.–14 adaptor thread)
  - Secondary–(AC) TP 916D

The change interval for oil and fuel filters is listed in Table 5–4.

Application	Replacement Intervals (Fuel Sulfur Content Less Than 0.5 wt.%)
Highway Truck and Motor Coach	15,000 miles (24,000 km)
City Coach	6,000 miles (9,600 km)
Industrial, G Drive and Agricultural	150 hours

Table 5–4 Maximum Lubricating Oil and Fuel Filter Replacement Schedule

5.2.5 Used Lubricating Oil Analysis Guidelines

These values indicate the need for an immediate oil change, but do not necessarily indicate internal engine problems requiring engine teardown. Characteristics relating to lubricating oil dilution should trigger corrective action to identify and find the the source(s) of leaks, if these values are realized (listed in Table 5–5). Contact your DDC distributor or dealer regarding oil analysis services.

Warning Limits	ASTM Designation	Series 50 Limit
Pentane Insolubles–Mass %	D–893	1.0
Carbon (Soot) Content, Maximum–Mass %	E–1131	1.5
Viscosity at 40°C cS Maximum Increase–% & Maximum Decrease–%	D–445 & D–2161	40.0 & 15.0
Total Base Number (TBN) Minimum	D–664 or D–4739	1.0
Total Base Number (TBN) Minimum	D–2896	2.0
Water Content (Dilution), Maximum–Vol. %	D–95	0.30
Flash Point, Maximum Reduction–°F	D–92	20.0
Fuel Dilution, Maximum–Vol. %	†	2.5
Glycol Dilution, Maximum–ppm	D–2982	1000
Iron Content, Maximum–ppm (Fe)	‡	150
Sodium Content, Maximum Allowed Over Lubricating Oil Baseline–ppm	‡	50
Boron Content, Maximum Allowed Over Lubricating Oil Baseline–ppm	†	20
Copper Content, Maximum–ppm (Cu)	†	30
Lead Content, Maximum–ppm	‡	100
Tin Content, Maximum–ppm	‡	40
Silicon Content, Maximum–ppm	‡	20
Chrome Content–ppm	‡	15

† No ASTM procedure designation.

‡ Elemental analyses are conducted using either emission or atomic absorption spectroscopy. Neither method has an ASTM designation.

Table 5–5 Used Lubricating Oil Analysis Guidelines for Immediate Oil Change

5.2.6 Miscellaneous Fuel and Lubricant Information

A list of "brand" name lubricants distributed by the majority of worldwide oil suppliers can be purchased from the Engine Manufacturers Association (EMA). The publication is titled *EMA Lubricating Oils Data Book for Heavy-Duty Automotive and Industrial Engines*. The publication shows the brand names, oil performance levels, viscosity grades, and sulfated ash contents of most "brands" marketed.

ENGINE MANUFACTURERS ASSOCIATION

401 NORTH MICHIGAN AVE.

CHICAGO, ILLINOIS 60611–4267

5.3 COOLANT

The coolant provides a medium for heat transfer and controls the internal temperature of the engine during operation. In an engine having proper coolant flow, some of the heat of combustion is conveyed through the cylinder walls and the cylinder head into the coolant. Without adequate coolant, normal heat transfer cannot take place within the engine, and engine temperature rapidly rises. Therefore, coolant must be carefully selected and properly maintained.

The following terms are used throughout this section and must be understood.

- Coolant – The fluid mixture circulating in the engine cooling system.
- IEG – Full strength (non–diluted) Inhibited Ethylene Glycol meeting applicable heavy–duty formulation specifications.
- IPG –Full strength (non–diluted) Inhibited Propylene Glycol meeting applicable heavy–duty formulation specifications.
- SCA – Supplemental Coolant Additives. Used to prevent corrosion, cavitation, and the formation of deposits.
- Initial fill – Any time the cooling system is empty, then filled with new coolant.
- Precharged IEG – Also referred to as a – fully formulated IEG. Contains the proper amount of SCA. Additional SCA must not be used with a precharged IEG at initial fill.
- Precharged IPG – Also referred to as a – fully formulated IPG. Contains the proper amount of SCA. Additional SCA must not be used with a precharged IPG at initial fill.
- Dropout – Sludge or deposit formation in or on cooling system components.

Using a coolant with the appropriate concentrations of SCA is one of the most important aspects of quality engine maintenance. To achieve the chemical balance needed to protect a cooling system, certain coolant basics must be understood.

This section provides the directions and information required to ensure cooling system protection for Detroit Diesel Series 50 engines. These recommendations are general rules and reflect the current technology. Specific concerns not covered should be addressed to your local Detroit Diesel representative.

The coolant used in Detroit Diesel Series 50 engines must meet the following basic requirements:

- Provide an adequate heat transfer medium.
- Protect against cavitation damage.
- Provide a corrosion/erosion–resistant environment.
- Prevent formation of scale or sludge deposits.
- Be compatible with cooling system hose and seal materials.
- Provide adequate freeze protection.

A properly maintained coolant can be used for two years, 200,000 miles, or 4000 hours, whichever comes first. At this time the cooling system must be drained, thoroughly cleaned and filled with new coolant.

To achieve these requirements, coolants are mixtures of good quality water, SCA and often an IEG or IPG for freeze protection. The rest of this bulletin will describe the requirements and usage of the water, SCA, IEG, and IPG.

5.3.1 Water

Water is the best practical medium for heat transfer. However, water alone can cause corrosion and inherently contains minerals that can produce scale deposits on internal cooling system surfaces. Chlorides, sulfates, magnesium, and calcium dissolved in the water can cause scale deposits, sludge deposits and/or corrosion.

Distilled or deionized water is preferred to minimize the adverse effects of minerals in water. The maximum allowable limits for minerals in water are listed in Table 5–6. The procedure for evaluating the quality of water is shown in the next illustration. see Figure 5–2.

Mineral	Limit–ppm	Limit – grains per gallon
Chlorides	40	2.5
Sulfates	100	5.8
Total dissolved solids	340	20
Total Hardness: Magnesium & Calcium	170	10

Table 5–6 Maximum Allowable Limits for Minerals in Water

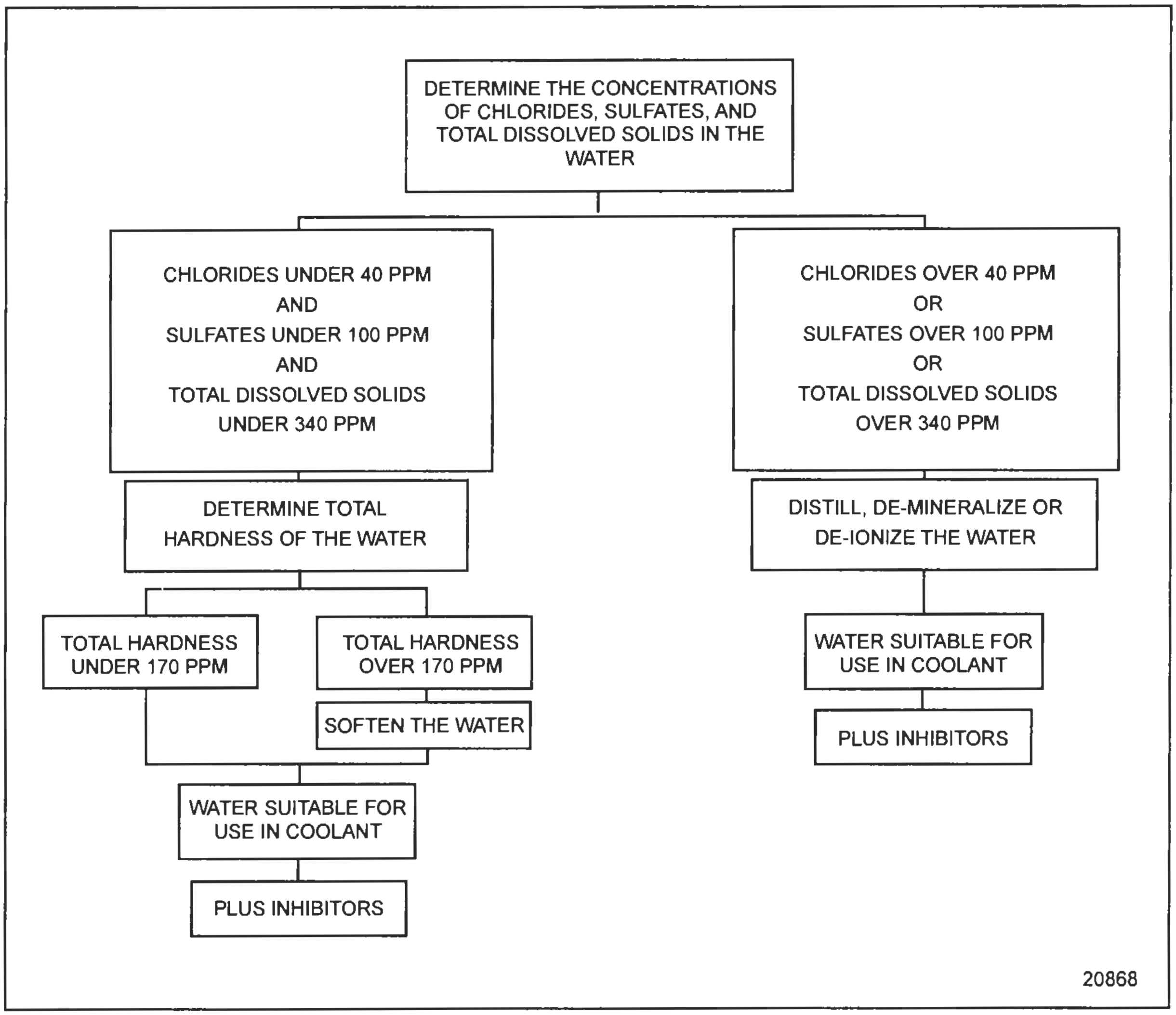


Figure 5–2 Water Evaluation Procedure

5.3.1.1 Antifreeze, Inhibited Ethylene Glycol

Ethylene glycol is used for freeze protection of the coolant. IEG, commonly referred to as "antifreeze," also contains chemicals that provide a limited protection against corrosion. The use of an IEG product with a low silicate formulation that meets either the GM 6038–M formulation (GM1899–M performance) or ASTM D 4985 requirements is recommended.

5.3.1.2 Antifreeze, Inhibited Propylene Glycol

An IPG/water mixture provides freeze protection.

Propylene glycol must meet the performance requirements of ASTM D 4985 and the physical/chemical requirements of ASTM D5216. The maintenance procedures for propylene glycol are the same as for IEG. All references to IEG will also apply to IPG for the Series 50 engines.

For best overall performance, a 50% concentration of IEG (1/2 IEG, 1/2 water) is recommended. An IEG concentration over 67% (2/3 IEG, 1/3 water) is not recommended because of poor heat transfer, reduced freeze protection, and possible silicate dropout. An IEG concentration below 33% (1/3 IEG, 2/3 water) offers little freeze or corrosion protection and is not recommended (see Figure 5–3, see Figure 5–4, and see Figure 5–5).

IEG coolants require the addition of SCA to provide cooling system corrosion and deposit protection. The SCA added should match the chemistry of the additive package included in the coolant. If this precaution is not observed, coolant monitoring can become difficult, making over inhibiting more likely. IEG formulations available in the market may contain from zero to the full amount of the required SCA. A basic IEG with no SCA must have additional SCA added at the time of initial fill. A Fully Formulated or Precharged IEG such as Detroit Diesel Powercool® already contains the required SCA (listed in Table 5–7). Over concentration will result if SCAs are added to a fully formulated IEG coolant at the time of initial fill. This can result in solids dropout and the formation of deposits.

POWERCOOL®–DDC Part Number	Size
23512138	1 gallon
23512139	55 gallons
23512140	bulk

Table 5–7 Powercool® Fully Formulated/Precharged IEG

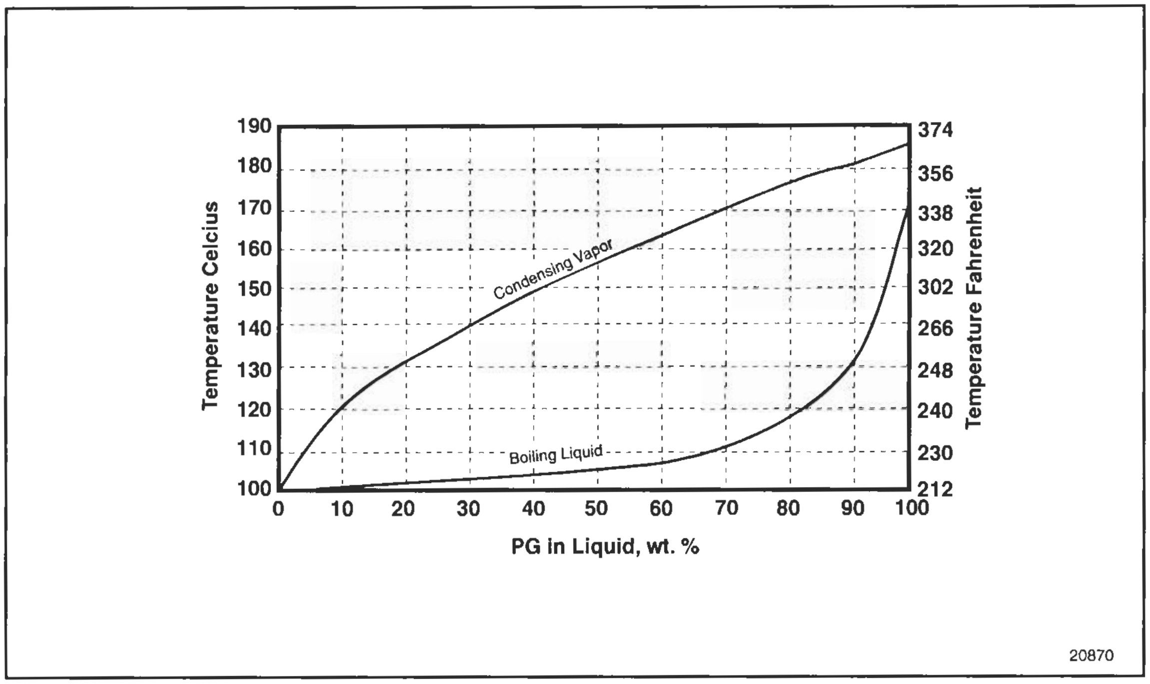


Figure 5–3 IPG Boiling Point

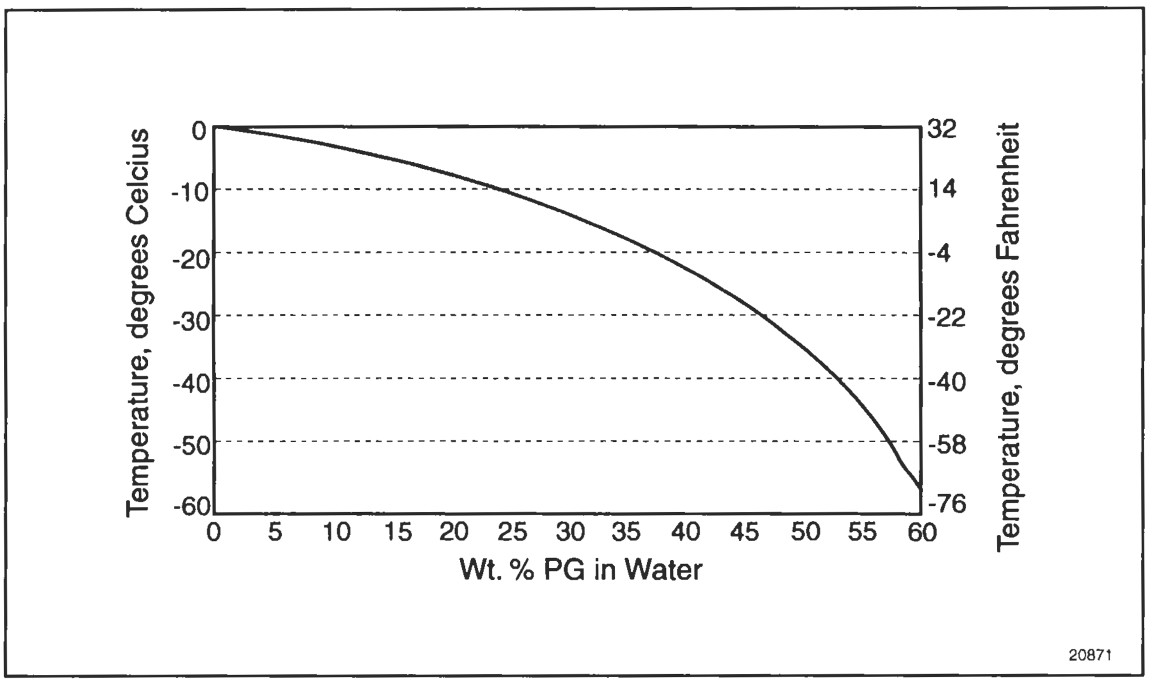


Figure 5–4 IPG Freezing Point

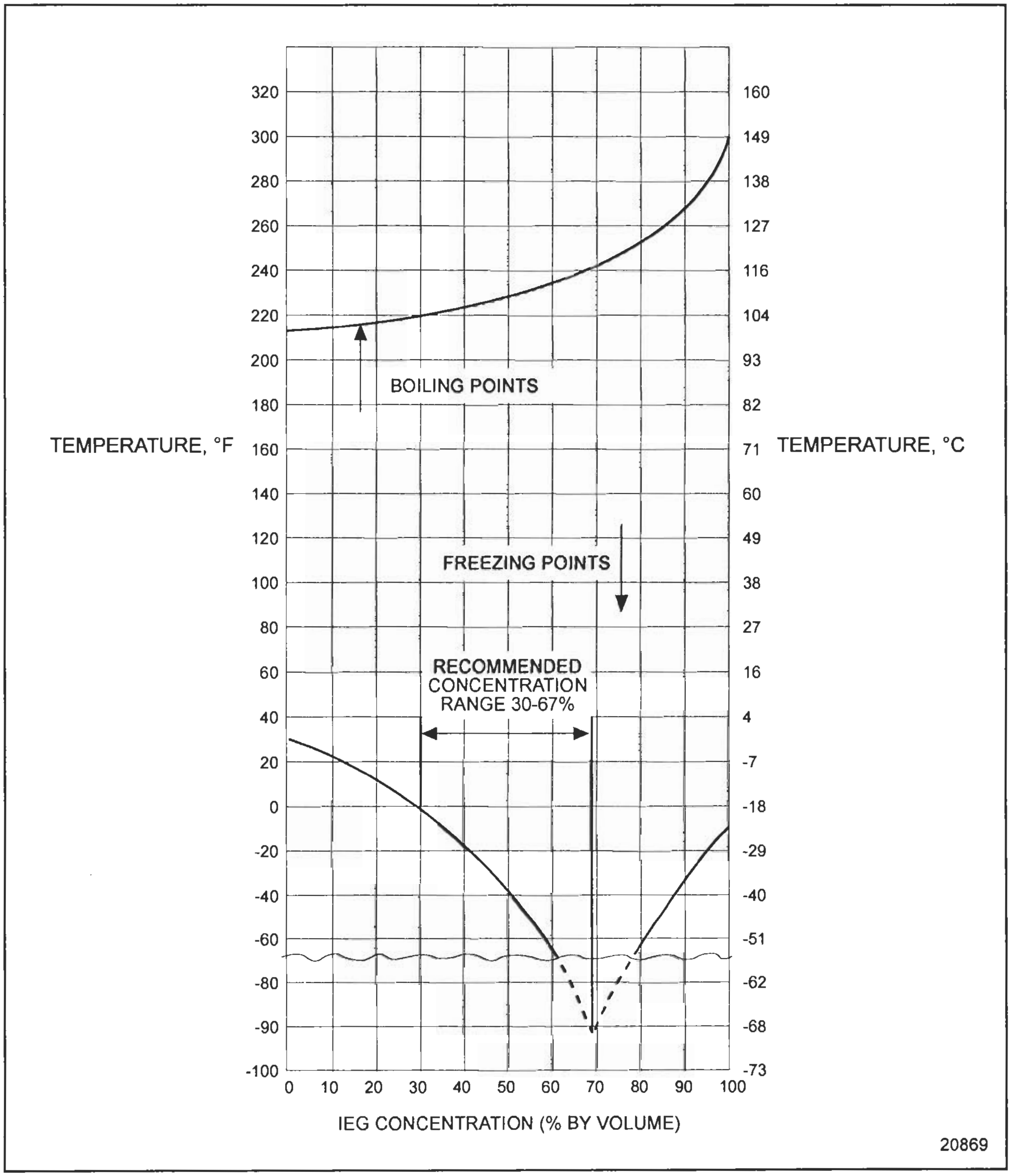


Figure 5–5 Coolant Freezing and Boiling Temperature vs. Inhibited Ethylene Glycol Concentration (Sea Level)

5.3.2 Coolants Not Recommended

Methyl alcohol–based antifreeze should not be used in Detroit Diesel Series 50 engines because of its effect on the non–metallic components of the cooling system and its low boiling point. Similarly, methoxy propanol–based antifreeze should not be used in Detroit Diesel Series 50 engines because it is not compatible with fluoroelastomer seals found in the cooling system. Glycol–based coolants formulated for heating/ventilation/air conditioning (HVAC) should not be used in Detroit Diesel Series 50 engines. These coolants generally contain high levels of phosphates, which can deposit on hot internal engine surfaces and reduce heat transfer.

5.3.3 Supplemental Coolant Additive

SCAs provide protection for the cooling system components. The coolant must have the proper concentration of SCAs. Detroit Diesel Maintenance Products are recommended for use in Detroit Diesel Series 50 engines.

NOTICE:
Excessive amounts of chemicals in the engine coolant can cause a gel–type or crystalline deposit that reduces heat transfer and coolant flow. The deposit, called dropout takes the color of the coolant when wet, but appears as a white powder when dry. It can pick up solid particles in the coolant and become gritty, causing excessive wear of water pump seals and other cooling system components. The wet gel can be removed by non–acid (alkali) type heavy–duty cleaner, Detroit Diesel Maintenance Product cleaner DD–2001 (sodium nitrite/sodium tetraborate). If the gel is allowed to dry, it is necessary to disassemble the engine and clean with a caustic solution or mechanically clean individual components.

The proper application of SCA will provide:

- A pH control to prevent corrosion.
- Water–softening to deter formation of mineral deposits.
- Cavitation protection to reduce the effects of cavitation.

The proper dosage for initial cooling system fill is listed in Table 5–8. Maintenance cooling system fill is listed in Table 5–9, initial coolant inhibitor element size requirements for IPG and IEG plus water coolant mixtures are listed in Table 5–10. Coolant inhibitor element size requirements, initial dosage for water–only systems, are listed in Table 5–11. The proper maintenance dosages are listed in Table 5–12.

Coolant	Coolant Element	Liquid
Precharged IEG and Water	NONE	NONE
IEG and Water	Select Element listed in Table 5–10.	3% by Volume, or 1 pint per 4 gallons
Water only	Select Element listed in Table 5–11.	6% by Volume, or 1 quart per 4 gallons

NOTE: 1 gallon= 3.785 L; 2 pints= 1 quart; 4 quarts= 1 gallon

Table 5–8 Initial Fill SCA Dosage

Coolant Element	Liquid
Select element listed in Table 5–12.	0.6% by Volume or 1 pint per 20 gallons

NOTE: 1 gallon= 3.785 L; 8 pints per gallon

Table 5–9 Maintenance SCA Dosage

Cooling System Capacity, Gallons (L)	Quantity	DDC Part Number	NALCO Part Number
9–12 (34–45)	1	23508426	DDF–3000.12
13–16 (49–61)	1	23507189	DDF–60.16
24–32 (91–121)	1	23508427	DDF–3000.32

Table 5–10 Coolant Inhibitor Element Size Requirements–Initial Fill Dosage for IEG or IPG plus Water Coolant Mixtures

Cooling System Capacity Gallons (L)	SCA Element Quantity	Detroit Diesel SCA Element Part Number	Additional SCA Liquid Required	Nalco Element Part Number
5 (19)	1	23508427	DDF–3000.4	None
7 (26)	1	23508426	DDF–3000.12	None
10 (38)	1	23507189	DDF–60.12	None
15 (57)	2	23508426	DDF–3000.12	None
20 (77)	1	23508427	DDF–3000.32	None
25 (95)	1	23508427	DDF–3000.32	None
30 (114)	1	23508427	DDF–3000.32	None
30 (114)	1	23508426	DDF–3000.12	None

Table 5–11 Coolant Inhibitor Element Size Requirements–Initial Dosage for Water–Only System

Cooling System Capacity, Gallons (L)	Quantity	DDC Part Number	NALCO Part Number
9–12 (34–35)	1	23507545	DDF–3000
13–16 (49–61)	1	23507545	DDF–3000
24–32 (91–121)	1	23508425	DDF–3000.8

Table 5–12 Coolant Inhibitor Element Size Requirements–Maintenance Dosage for IEG, IPG, Precharged, and Water–Only Coolant Mixture

The concentration of SCA will gradually deplete during normal engine operation. Check the SCA concentration at the regular intervals listed in Table 5–13. Additional SCA must be added to the coolant when it becomes depleted below a specified level (listed in Table 5–14). Maintenance dosage of SCA must only be added if nitrite concentration is less than 800 ppm. If nitrite concentration is greater than 800 ppm, do not add additional SCA.

Service Application	Inhibitor Test Interval
On–highway Trucks and Motor Coaches	15,000 miles (24,000 km)
City Transit Coaches, Pick–up and Delivery, Short Trip, and Emergency Vehicles	6,000 miles (9,600 km) or three months, whichever comes first.
Industrial, Generator Set, and all other applications	200 hours or yearly, whichever comes first.

Table 5–13 Required Coolant Inhibitor Test Intervals

SCA	Minimum SCA ppm	Maximum SCA ppm
Boron (B)	1,000	1,500
Nitrite (NO_2)	800	2,400
Nitrates (NO_3)	1,000	2,000
Silicon (Si)	50	250
Phosphorus (P)	0	500
pH	8.5	10.5

Table 5–14 SCA Limits with GM6038–M or ASTM–D 4985 (50/50 Coolant/Water Mixture)

5.3.4 Soluble Oils

Soluble oil additives are not approved for use in the Detroit Diesel Series 50 engine cooling systems. A small amount of oil adversely affects heat transfer. A 1.25% concentration of soluble oil increases the fire deck temperature 6%. A 2.50% concentration increases the fire deck temperature 15%.

5.3.5 Chromate

Chromate additives are not approved for use in the Detroit Diesel Series 50 engine cooling systems. Chromate additives can form chromium hydroxide, commonly called "green slime." This, in turn, can result in engine damage due to poor heat transfer. Cooling systems operated with chromate–inhibited coolant must be chemically cleaned with Nalco 2015 cooling system cleaner and conditioner (or equivalent sulfamic acid/sodium carbonate cleaner) and flushed.

Some coolant filter elements with magnesium internal support plates have caused engine damage. The coolant dissolves the magnesium and deposits it on the hot zones of the engine where heat transfer is most critical. The use of elements with these plates is not approved.

5.3.6 Detroit Diesel Cooling System Maintenance Products

Detroit Diesel Maintenance Products SCA are water–soluble chemical compounds. These products are available in coolant filter elements, liquid packages, and a fully formulated IEG.

5.3.7 Coolant Filter Elements

Replaceable coolant filter elements (spin–on canisters) are available in various sizes suitable for cooling systems of varying capacity. Selection of the proper element size is vital when precharging the coolant system at initial fill and at maintenance intervals.

NOTE:
A fully formulated IEG or IPG must NOT have SCA added at initial fill.

The need for maintenance elements is determined by the results of the SCA concentration test performed at each cooling system service interval.

5.3.8 Supplemental Coolant Additive Test Procedures

Nitrite concentration is an indication of the SCA concentration in the coolant. Nitrite test kits and test strips are commercially available. The coolant must be tested for required inhibitor levels at the intervals listed in Table 5–13. SCA levels must be within the ranges listed in Table 5–14.

NOTICE:

Do not use Detroit Diesel **POWERTrac®** test strips to determine the inhibitor levels of coolant with non–DDC approved additive packages. Incompatible chemicals and variance in inhibitor levels in the additive packages may cause inaccurate interpretation of test strip readings. This can lead to under–inhibiting the coolant, which may result in cavitation erosion.

5.3.8.1 Liquid Supplemental Coolant Additive

Detroit Diesel Cooling System Maintenance Procedures SCA and Cleaners are available in liquid form and are listed in Table 5–15.

Product	Size	DDC Part No.
NALCOOL® 2000–Liquid SCA	1 pint (12 per case)	23507858
NALCOOL® 2000–Liquid SCA	half gallon (6 per case)	23507859
NALCOOL® 2000–Liquid SCA	5 gallons	23507860
NALCOOL® 2000–Liquid SCA	55 gallons	23507861
NALCOOL® 3000 †– Liquid SCA	1 pint (12 per case)	23507854
NALCOOL® 3000 †– Liquid SCA	half gallon (6 per case)	23507855
NALCOOL® 3000 †– Liquid SCA	5 gallons	23507856
NALCOOL® 3000 †– Liquid SCA	55 gallons	23507857
NALPREP® 2001 ON–LINE CLEANER	half gallon (6 per case)	23507862
NALPREP® 2001 ON–LINE CLEANER	5 gallons	23507863
NALPREP® 2001 ON–LINE CLEANER	55 gallons	23507864
NALCOOL® 2015, Twin Pac, Dry, Chemical Cleaner/Conditioner	2 per case	23507867

† Nalcool 3000 is more compatible with hard water than Nalcool 2000. Use Nalprep 2001 for light deposits. Use Nalprep 2015 for heavy deposits or scale. Nalcool® and Nalprep® are licensed trademarks of the Penray Companies.

NOTE: 1 gallon=3.785 L; 8 pints=1 gallon

Table 5–15 Liquid SCA and Additional Coolant Treatment Products

5.3.8.2 Test Kit Procedures

Use Detroit Diesel Powertrac® 2-Way Coolant Test Strips (part number 23515917) to measure nitrite and glycol concentrations. Cavitation/corrosion protection is indicated on the strip by the level of nitrite concentration.

NOTICE:
Failure to properly maintain coolant with SCA can result in damage to the cooling system and its related components. Conversely, over concentration of SCA inhibitor can result in poor heat transfer, leading to engine damage. Always maintain concentrations at recommended levels.

Freeze/boil over protection is determined by glycol concentration. Use the test strips as follows:

1. Dip the strip into coolant for one second. Remove and shake briskly to eliminate excess fluid.
2. Immediately compare end pad (% glycol) to the color chart.
3. Sixty seconds (one minute) after dipping, compare the nitrite pad.

For best results make the tests while the coolant is between 50 and 140°F (10–60°C). Wait at least 60, but not longer than 75 seconds before reading the nitrite level. Promptly replace and tighten container cap after each use. Discard unused strips if they have turned light pink or tan.

A factory coolant analysis program is also available through authorized Detroit Diesel service outlets under part number 23508774.

5.3.9 Summary of Coolant Recommendations

Coolant recommendations may be summarized as follows:

> **CAUTION:**
>
> **Never remove the cooling system fill (pressure) cap while coolant is hot. The system may be under pressure. Remove the cap slowly and only when coolant is at ambient temperature. A sudden release of pressure from a heated cooling system can result in personal injury from the splash of hot coolant.**

1. Always maintain the engine coolant to meet Detroit Diesel specifications.

NOTE:
Propylene glycol meeting ASTM D 4985, and ASTM D 5216 is approved for use in Series 50 engines.

2. Only use water that meets Detroit Diesel specifications. Distilled or deionized water is preferred.
3. The proper dosage of SCA must be included in the coolant at initial fill for all Detroit Diesel Series 50 engines.

This dosage can be either included in part or entirely in the IEG used, or it may need to be added. Dosage is also dependent on whether water or IEG is used. The user is urged to refer to the full text of this bulletin to determine the proper dosage. Mixing of different manufacturers' inhibitors (SCAs) could cause cooling system problems.

4. Maintain the SCA to the prescribed concentration. Test the nitrite concentration by using a titration kit or Detroit Diesel 2–Way Coolant Test Strips. Add SCA only if the nitrite concentration is below 800 ppm.

Do not use another manufacturer's test kit to measure the SCA concentration of Detroit Diesel Maintenance Products.

5. Pre–mix coolant makeup solutions at the proper concentration before adding to the coolant system.

6. Where antifreeze/boil over protection is required, use only ethylene glycol coolant (low silicate formulation) meeting GM 6038–M, GM 1899–M, or ASTM D 4985.
7. Always maintain proper coolant level.
8. A properly maintained cooling system can be operated for up to two years, 200,000 miles (320,000 km) or 4000 hours, whichever comes first. At this interval the cooling system must be thoroughly cleaned and the coolant replaced.
9. Do not use the following in Detroit Diesel engine cooling systems:
   - ❑ Soluble oil
   - ❑ Chromate SCA
   - ❑ Methoxy propanol–base coolant
   - ❑ Methyl alcohol–base coolant
   - ❑ Sealer additives or coolant containing sealer additives
   - ❑ HVAC coolant

6 AIR INTAKE SYSTEM

Section | Page

6.1 AIR INTAKE SYSTEM OVERVIEW

The air intake system consists of the following components:

- ❑ Air cleaner
- ❑ Intake manifold
- ❑ Turbocharger
- ❑ Charge air cooler
- ❑ Air dryer

The turbocharger supplies air under pressure to the intake manifold. The air enters the turbocharger after passing through the air cleaner. Power to drive the turbocharger is extracted from energy in the engine exhaust gas. The expanding exhaust gases turn a single stage turbocharger wheel, which drives an impeller, thus pressuring intake air. This charge air is then cooled by an air–to–air heat exchanger before the engine intake manifold for improved combustion efficiency. See Figure 6–1.

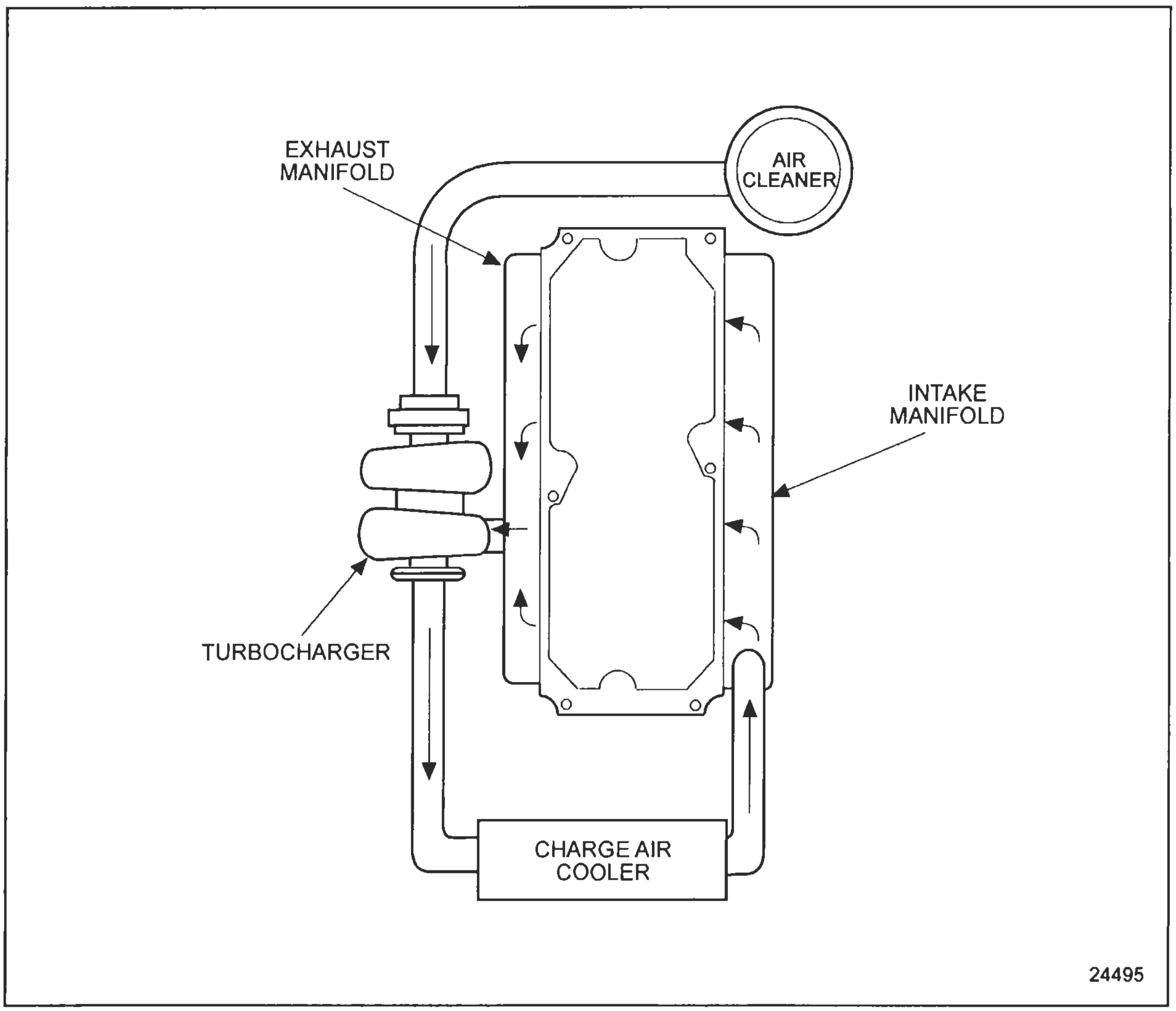


Figure 6–1 Air Intake System Schematic

A charge air cooler (CAC) is mounted ahead of the engine coolant radiator. The pressurized intake charge is routed from the discharge side of the turbocharger, through the CAC to the intake manifold, which directs the air to ports in the cylinder head, through two intake valves per cylinder, and into each cylinder. At the beginning of the compression stroke, each cylinder is filled with clean air.

Repair and replacement procedures for the individual components of the air intake system are contained in this section.

6.2 AIR CLEANER

Air cleaners are designed to remove foreign matter from the air and pass the required volume of air for proper combustion. Manufacturers guidelines should be consulted to maintain efficient operation for a reasonable period of time before requiring service.

The importance of keeping dust and grit–laden air out of the engine cannot be overemphasized, since clean air is essential to satisfactory engine operation and long engine life. Should dust in the air supply enter the engine, it would be carried into the cylinders and, due to its abrasive properties, cause premature wear of the moving parts. Dirt, which is allowed to build up in the air cleaner passages, will eventually restrict the air supply to the engine and result in heavy carbon deposits on the valves and pistons due to incomplete combustion. The air cleaner must have a capacity large enough to retain the material separated from the air to permit operation for a reasonable length of time before cleaning is required.

NOTICE:
Detroit Diesel is aware of attempts to use air cleaner elements made of foam or fabric batting material soaked with a sticky substance to improve dirt–holding capability. In some installations this substance has been found to transfer from the filter media, coating the inside surfaces of air ducts and engine air inlet systems, blowers, air boxes, and turbochargers. The result has been reduced engine performance and a change in engine operating conditions.

Only oil bath type and dry paper element type air cleaners are recommended for use on all Detroit Diesel Series 50 engines. Alternate types of air filtration systems may be available in the after–market. Detroit Diesel does not recommend use or extend warranty to cover damage or malfunction of engine components as a result of usage on Detroit Diesel Series 50 engines.

If a foam or fabric air cleaner element soaked with a sticky, dirt–holding substance was previously installed, check for the presence of coated engine components. Remove and clean coated engine components as required.

6.2.1 Repair or Replacement of Air Cleaner

Refer to the OEM guidelines for air cleaner service procedures.

6.2.2 Cleaning and Removal of Air Cleaner

Detroit Diesel does not offer air cleaners as original equipment on Series 50 engines.

NOTICE:
Always vacuum check air intake restriction indicators after cleaning to ensure proper operation. Failure to observe this step may result in faulty indicator readings, which may lead to inefficient engine operation and damage.

Refer to air cleaner manufactures guidelines for cleaning and removal procedures.

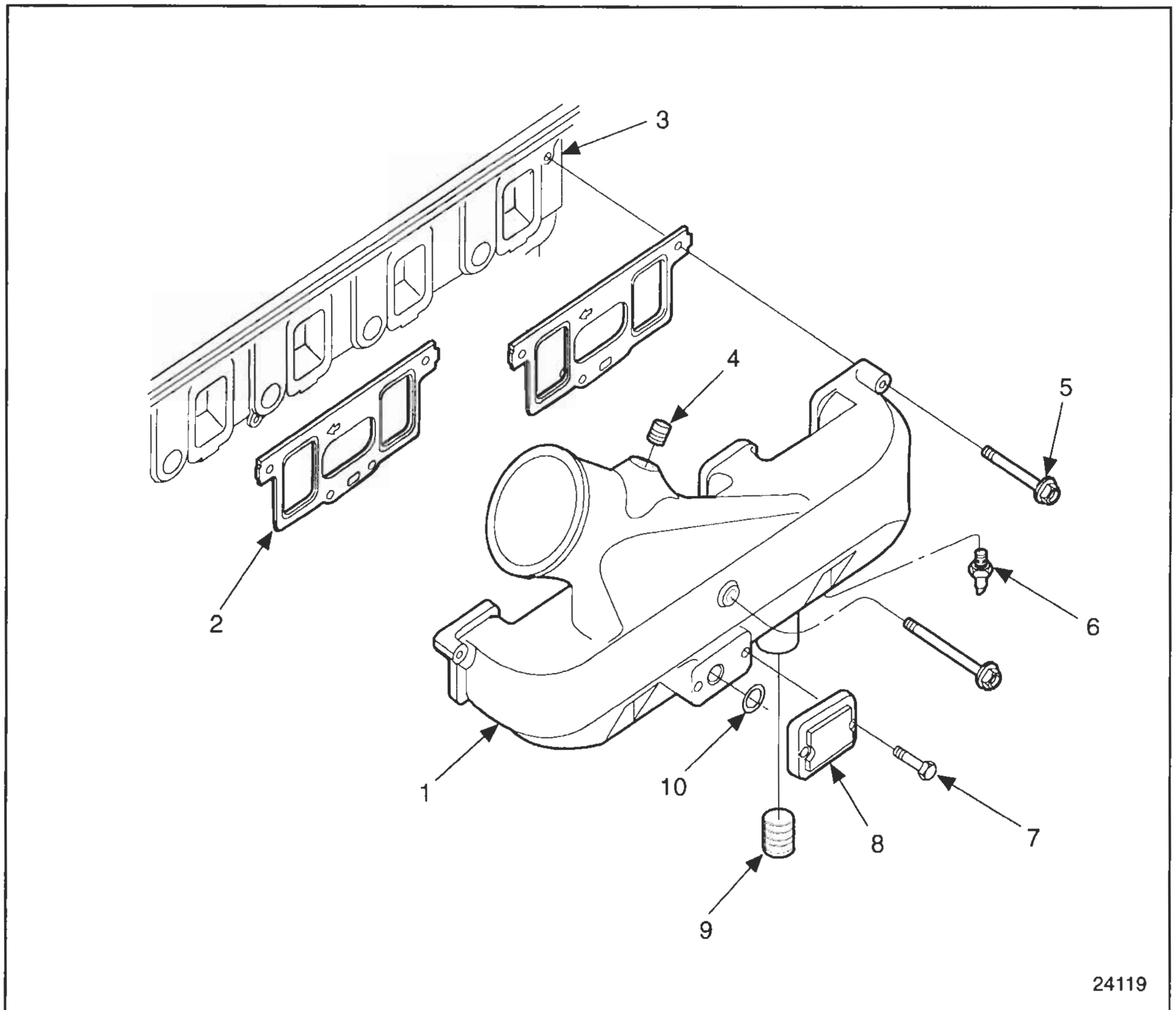
6.2.3 Installation of Air Cleaner

Refer to vehicle or equipment manufacturer for installation and verification procedures.

6.3 INTAKE MANIFOLD

The intake charge air is routed to the individual cylinders by an intake manifold that is bolted to the cylinder head with five bolts. The mating surface of the manifold and cylinder head is machined. The intake manifold is sealed to the cylinder head with two 2–port graphite coated gaskets. If the manifold is removed, new gaskets must be installed to maintain seal under higher boost pressure.

A turbo–boost pressure sensor and is mounted to the intake manifold with two bolts. An O–ring seals the boost sensor where it enters a hole in the manifold. On DDEC III engines there is an air temperature sensor located on the bottom of the manifold. See Figure 6–2. The intake manifold air inlet is attached to the CAC ducting and the air compressor using flexible hose and clamps.



1. Intake Manifold
2. Intake Manifold Gasket
3. Cylinder Head
4. Pipe Plug
5. Manifold Bolt
6. Air Temperature Sensor
7. Turbo–boost Pressure Sensor Bolt
8. Turbo–boost Pressure Sensor
9. Pipe Plug
10. O–ring

Figure 6–2 Intake Manifold and Related Parts

6.3.1 Repair or Replacement of Intake Manifold

To determine if repair is possible or replacement of the intake manifold is necessary preform the following procedure. See Figure 6–3.

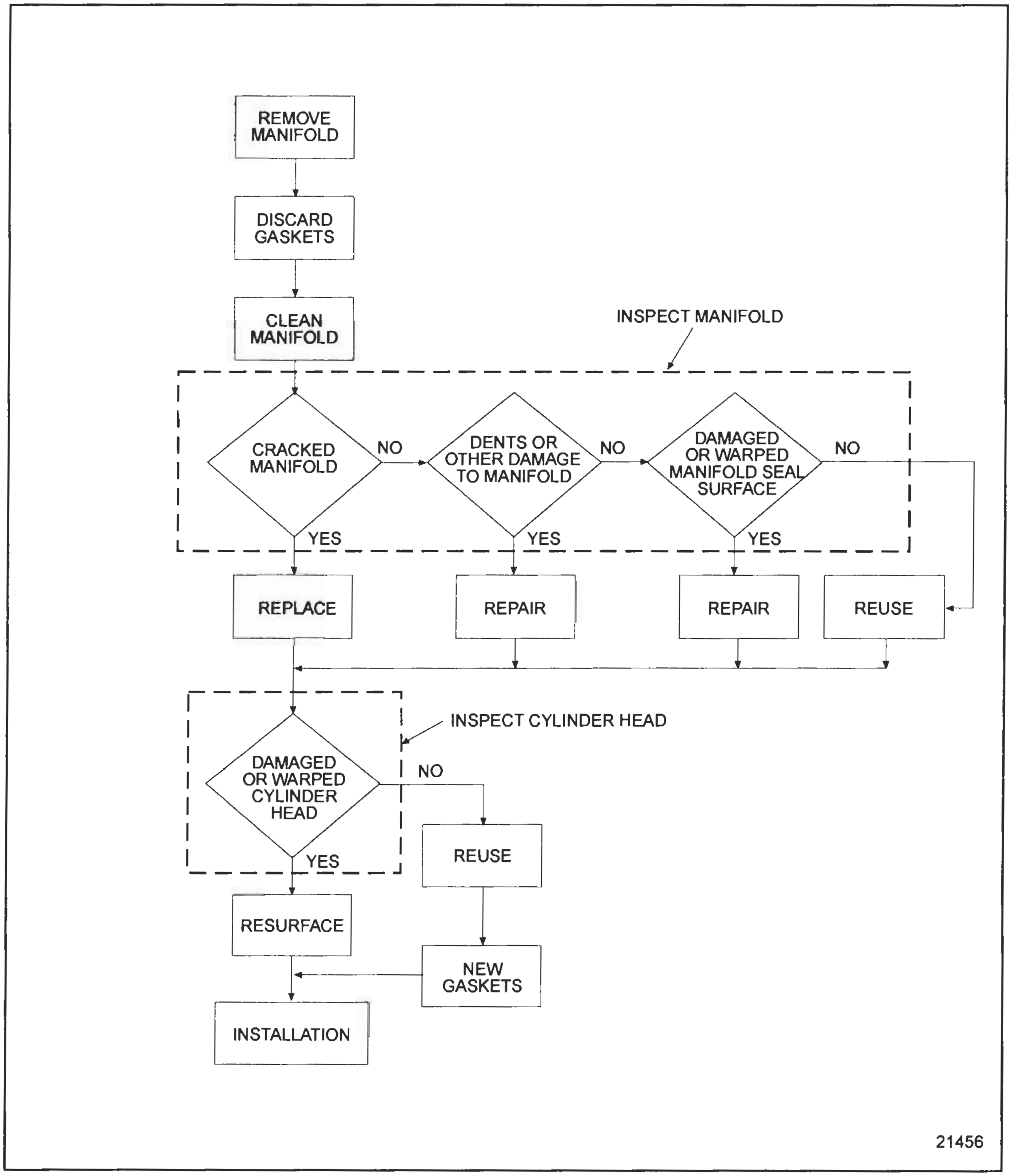


Figure 6–3 Flowchart for Repair or Replacement of Intake Manifold

6.3.2 Cleaning and Removal of Intake Manifold

Remove the intake manifold as follows:

1. Disengage the locking tang on the turbo–boost pressure sensor connector. Grasp the connector body and pull it straight out of the turbo–boost pressure sensor.
2. If servicing a DDEC III engine, disengage the locking tang on the air temperature sensor connector. Grasp the connector body and pull it straight out of the air temperature sensor.
3. Loosen the hose clamps connecting the hose coupling between the intake manifold and the CAC ducting. Slide the clamps and hose away from the intake manifold.
4. Remove the air compressor intake air line from the bottom of the intake manifold if used.
5. Loosen and remove the five bolts that retain the intake manifold to the cylinder head.
6. Tap the intake manifold lightly to separate the intake manifold from the cylinder head.
7. Remove and discard manifold seals.

NOTE:
Units built prior to 4R1945 may not have gasket seals.

8. Remove the intake manifold.

Clean the intake manifold, prior to inspection as follows:

NOTICE:
When removing and cleaning the intake manifold and cylinder head J 36571 *must* be used. Failure to do so may damage the intake manifold or cylinder head or both.

1. Remove loose gasket material from the cylinder head and intake manifold mating surfaces.

2. To clean the intake manifold mating surface and the head port area, use the surface conditioning set J 36571. See Figure 6-4.
   [a] To clean steel surfaces use a coarse grit disc (brown), part of the surface conditioning set, J 36571 with an electric or air powered hand drill operating at a speed of 15,000–18,000 r/min. The pads are easily interchangeable using the disc holder provided in the set.
   [b] To clean aluminum surfaces use a medium grit disc (maroon), part of the surface conditioning set, J 36571 with an electric or air powered hand drill operating at a speed of 15,000–18,000 r/min. The pads are easily interchangeable using the disc holder provided in the set.

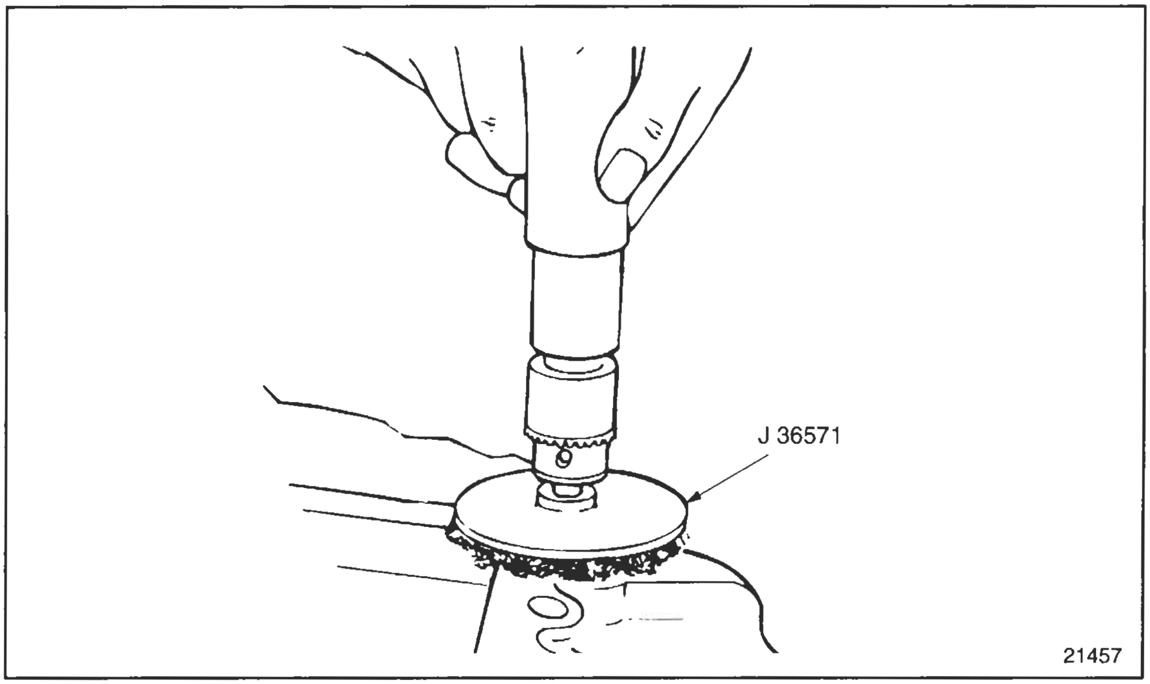


Figure 6–4 Cleaning the Manifold

3. Wash all of the parts in clean fuel oil.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

4. Blow dry with compressed air.

6.3.2.1 Inspection of Intake Manifold

Inspect the intake manifold as follows:

1. Visually inspect the manifold for any cracks, dents or other damage. Pay particular attention to the bolt areas.
   [a] If a crack is found, replace the intake manifold.
   [b] Refer to section 6.3.3 for installation procedure of new manifold.
2. Inspect the manifold mating surface for imperfections that could affect its sealing to the cylinder head.
   [a] Resurface as necessary.
3. Check the mating ports for warpage, using a 0.35 m (14 in.) long by 6 mm (.25 in.) wide straight edge bar laying the bar across the manifold.
   [a] If all port flange area measurements are less than 0.127 mm (.005 in.), the manifold is reusable and can be reinstalled with new gaskets. Refer to section 6.3.3 for installation.
   [b] If the manifold does not meet this requirement the manifold *must* be resurfaced.

6.3.3 Installation of Intake Manifold

Install the intake manifold as follows:

NOTICE:
It is necessary to completely seal the intake manifold to the cylinder head, due to the high pressure of the intake charge provided by the turbocharger. The arrow on the gasket must point to the front of the engine. Gasket eliminator can not be used with intake manifold seals. Failure to seal this interface will reduce engine performance.

1. Install two new manifold gaskets to the mating surfaces of the intake manifold with the arrow on the gasket pointing to the front of the engine. See Figure 6–5.

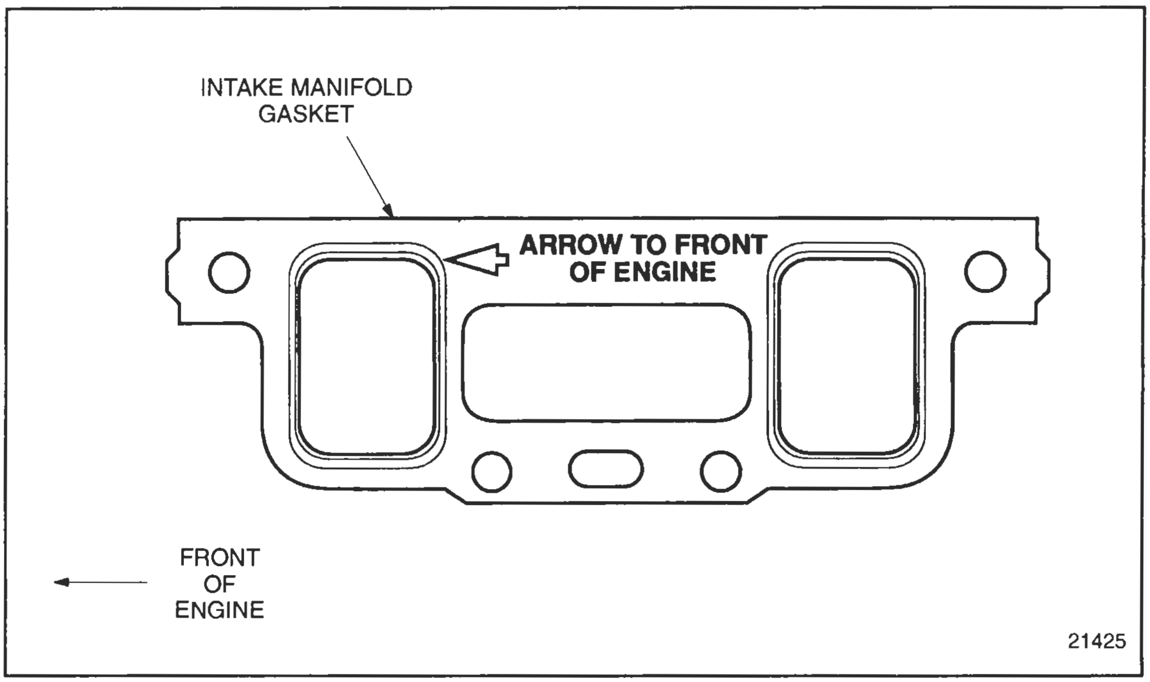


Figure 6–5 Intake Manifold Gasket Orientation

2. Install bolts four and five through the intake manifold and into the cylinder head and hand tighten. See Figure 6–6.

3. Install the three remaining bolts through the intake manifold and into the cylinder head. Tighten all of the intake manifold retaining bolts to 58–73 N·m (43–54 lb·ft) in the proper tightening sequence. See Figure 6–6.

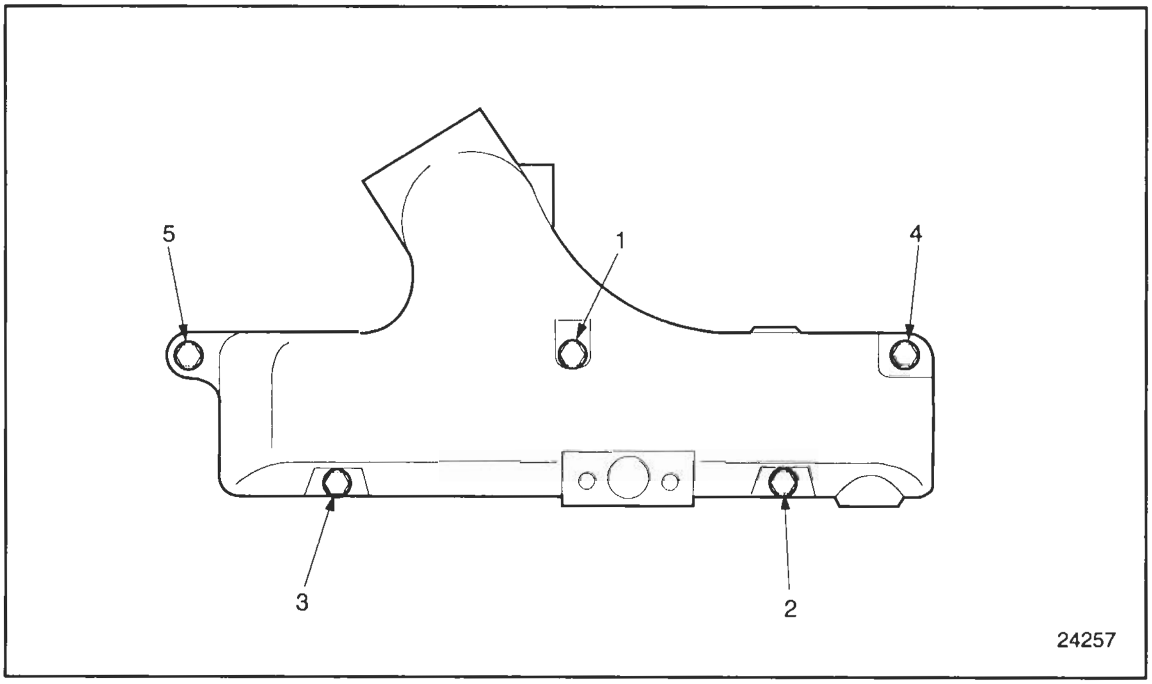


Figure 6–6 Intake Manifold Bolt Position and Torque Sequence

NOTE:
The numbers on this illustration signifies both position and torque sequence.

4. Plug in the turbo–boost pressure sensor wiring connector by pressing the connector into the body of the sensor until the locking tang snaps into place.

5. If servicing a DDEC III engine, plug in the air temperature sensor wiring connector by pressing the connector into the body of the sensor until the locking tang snaps into place.

CAUTION:

Do not use any type of lubricant on the inside of any air inlet hose or on the hose contact surfaces of the turbocharger compressor housing, CAC ducting or the intake manifold. Use of lubricant can cause the hose to blow off when the turbocharger builds boost pressure.

6. Slide the hose over the intake manifold and position it to its original location.
7. Slide the hose clamps into place and tighten them alternately. Insure that hose clamps are installed away from the cast bead on the manifold inlet to prevent separation of the joint.
8. Reattach air line to air compressor, if used, and tighten clamp.

6.4 TURBOCHARGER

The Garrett (formerly Airesearch) TV45 turbocharger is used on all Series 50 engines. See Figure 6–7.

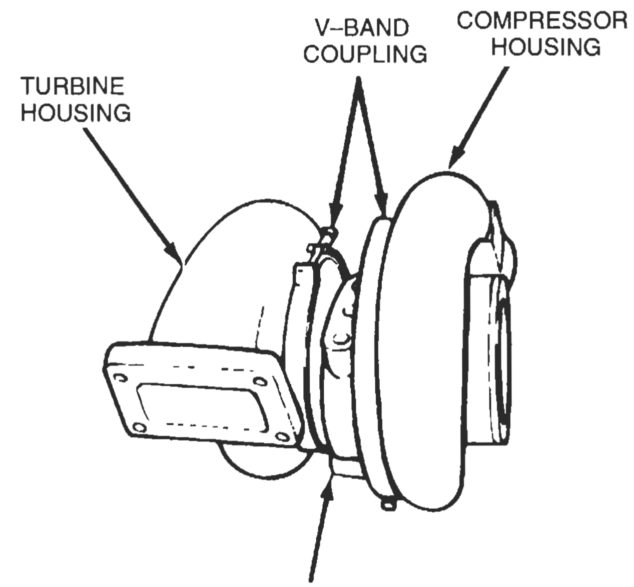


Figure 6–7 TV45 Turbocharger Assembly

The turbocharger is designed to increase the overall efficiency of the engine. Power to drive the turbocharger is extracted from the energy in the engine exhaust gas.

The turbocharger consists of a turbine wheel and shaft, a compressor wheel, and a center housing that serves to support the rotating assembly, bearings, seals, a turbine housing, and a compressor housing. The center housing has connections for oil inlet and oil outlet fittings.

The rotating assembly consists of a turbine wheel and shaft assembly, piston ring(s), thrust spacer, compressor wheel, and wheel retaining nut. The rotating assembly is supported on two pressure–lubricated bearings that are retained in the center housing by snap rings. Internal oil passages are drilled in the center housing to provide lubrication to the turbine wheel shaft bearings, thrust washer, thrust collar, and thrust spacer.

The turbine housing is a heat–resistant alloy casting that encloses the turbine wheel and provides a flanged engine exhaust gas inlet and an axially located turbocharger exhaust gas outlet. The turbine housing is secured to the turbine end of the center housing.

The turbocharger is mounted on the exhaust outlet flange of the engine exhaust manifold. After the engine is started, the exhaust gases flow from the engine and through the turbine housing causing the turbine wheel and shaft to rotate. See Figure 6–8.

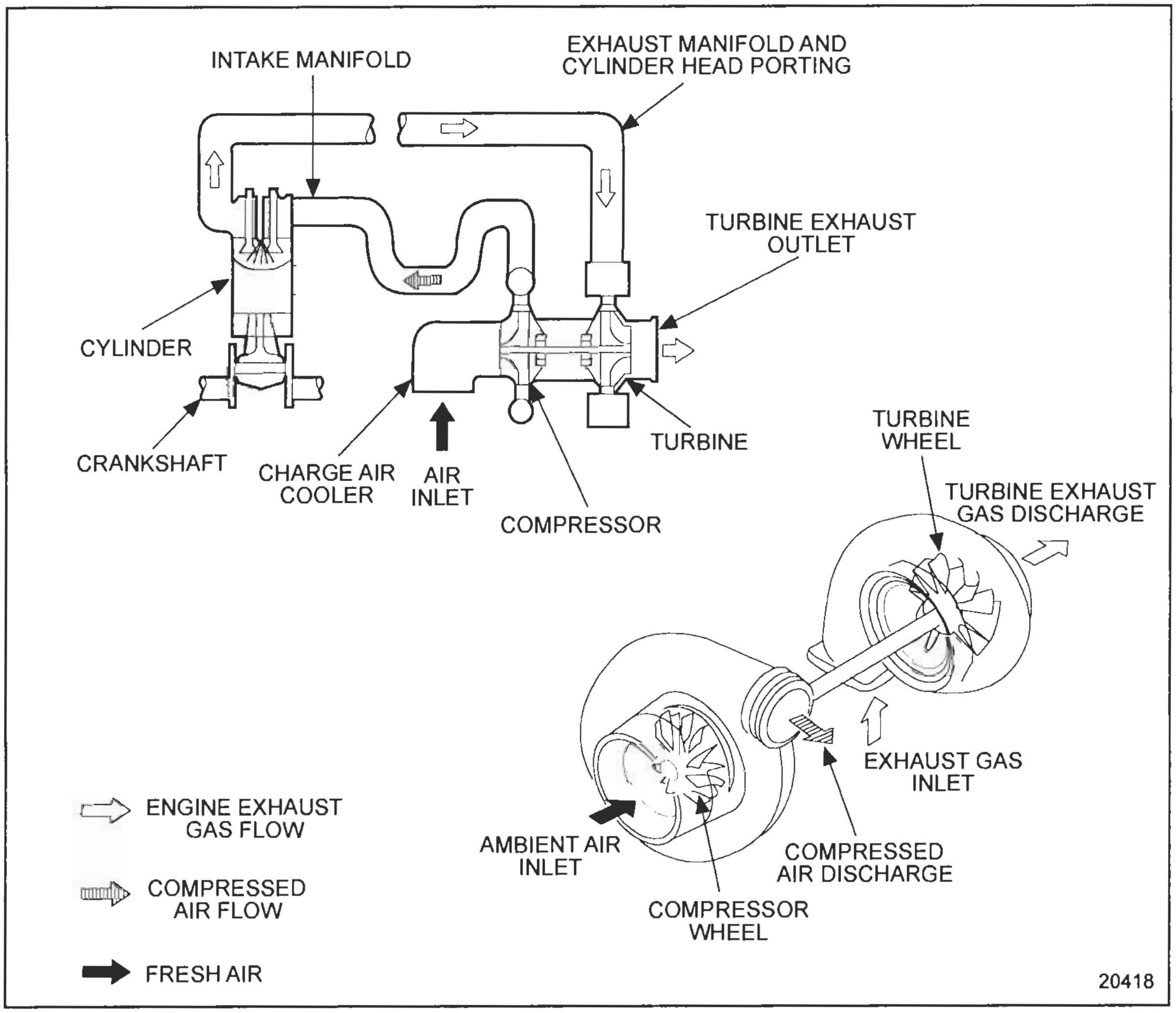
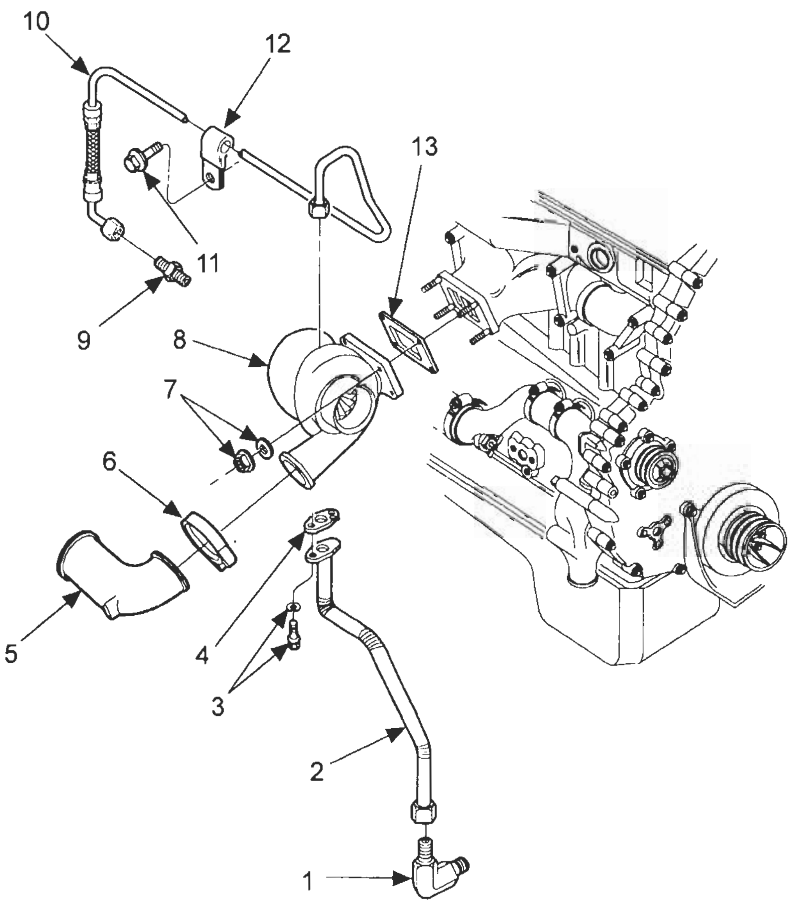


Figure 6–8 Schematic Air Flow Diagram

The gases are discharged into the exhaust system after passing through the turbine housing.

The compressor wheel, in the compressor housing, is mounted on the opposite end of the turbine wheel shaft and rotates with the turbine wheel. The compressor wheel draws in clean air, compresses it, and delivers high pressure air through the intake manifold to the engine cylinders.

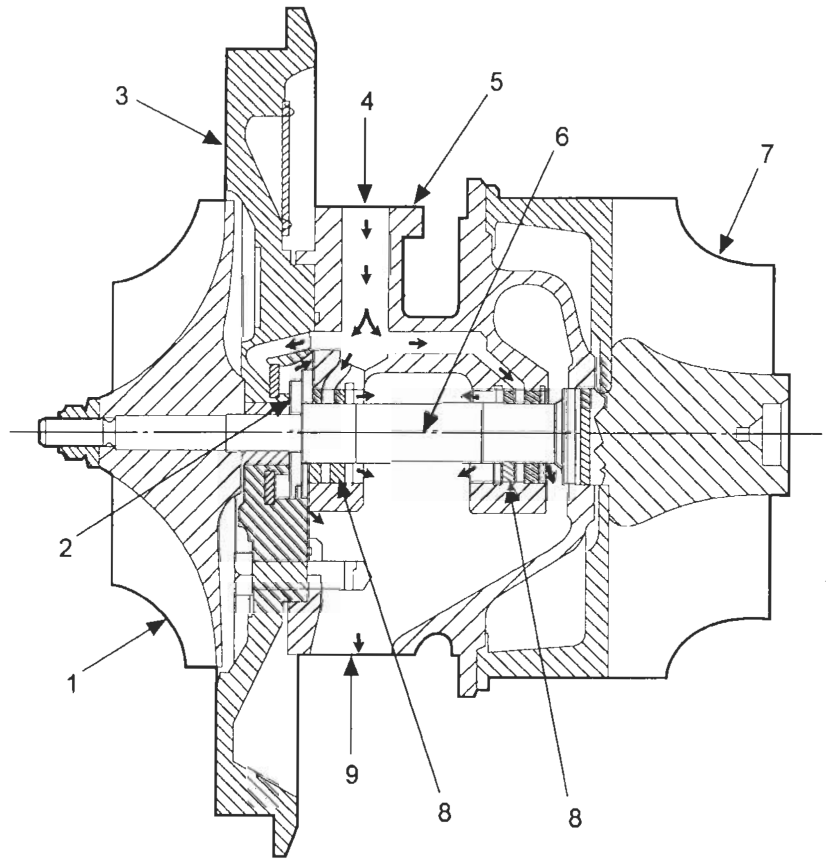
Oil for lubricating the turbocharger is supplied under pressure through an external oil line extending from the oil filter adaptor to the top of the center housing. See Figure 6-9.



1. Elbow, Oil Drain Tube
2. Tube, Turbo Oil Drain
3. Bolt, and Lockwashers, Oil Drain Tube Mounting
4. Gasket, Oil Drain Tube
5. Elbow
6. Clamp
7. Nut, and Washer Turbo Mounting
8. Turbocharger Assembly
9.. Connector, Oil Supply Tube (from oil filter adaptor)
10. Tube Assembly, Turbo Oil Supply
11. Bolt, Oil Supply Tube Clip
12. Clip, Oil Supply Tube
13. Gasket, Turbo Exhaust Inlet

Figure 6–9 Turbocharger Oil Lines

From the oil inlet in the center housing, the oil flows through the drilled oil passages in the housing to the shaft bearings, thrust ring, thrust bearing, and backplate or thrust plate. See Figure 6–10.



1. Compressor Wheel
2. Thrust Bearing
3. Backplate
4. Oil Inlet
5. Center Housing
6. Shaft
7. Turbine Wheel
8. Shaft Bearings
9. Oil Outlet

Figure 6–10 Turbocharger Oil Flow Diagram

The oil returns by gravity to the engine oil pan through an external oil line extending from the bottom of the turbocharger center housing to the cylinder block. See Figure 6–10.

6.4.1 Repair or Replacement of Turbocharger

To determine if repair is possible or replacement of the turbocharger is necessary perform the following procedure. See Figure 6-11.

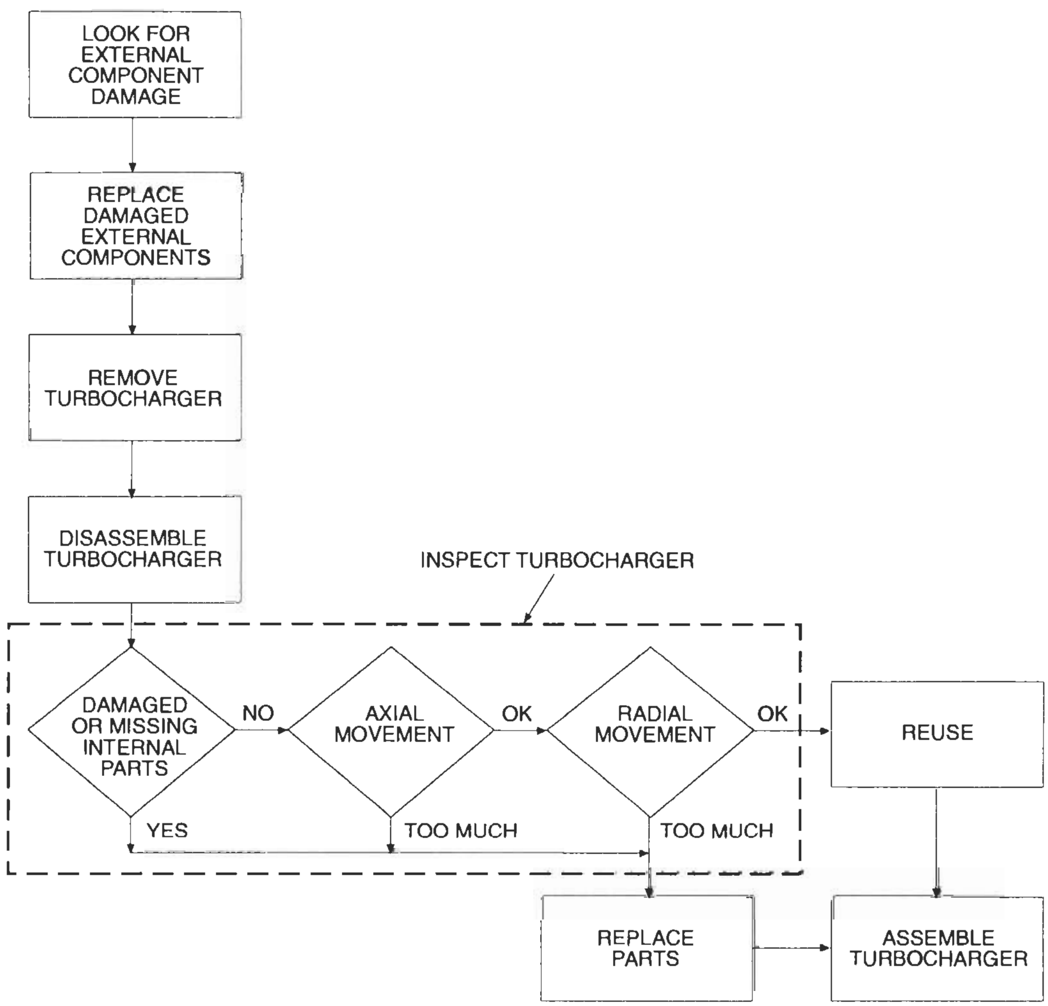


Figure 6–11 Flowchart for Repair or Replacement of Turbocharger

6.4.2 Cleaning and Removal of Turbocharger

Cleaning the turbocharger is not necessary before removal.

CAUTION:

Do not attempt to remove the turbocharger assembly until it has cooled. Touching a hot turbocharger assembly may result in personal injury.

Prior to removal, visually check for:

1. Missing or loose nuts and bolts.
2. Loose or damaged intake and exhaust ducting.
3. Damaged oil supply and drain lines.
4. Cracked or deteriorating turbocharger housings.
5. External oil leakage.
6. Replace damaged parts with new parts.

To remove the turbocharger, perform the following:

NOTICE:

Do not attempt to remove carbon or dirt buildup on the compressor or turbine wheels without removing the turbocharger from the engine. If chunks of carbon are left on the blades, an unbalanced condition will exist and subsequent failure of the bearings will result if the turbocharger is operated. However, it is not necessary to disassemble the turbocharger to remove dirt or dust buildup.

1. Disconnect and remove the CAC ducting at the compressor housing.
2. Disconnect and remove the air inlet hose attached to the compressor housing.
3. Disconnect the exhaust outlet pipe from the turbine housing of the turbocharger. For proper operation, the turbocharger rotating assembly must turn freely. Whenever the exhaust ducting is removed, spin the turbine wheel by hand.
4. Remove the inlet oil line from the top of the center housing.
5. Remove the oil drain line from the bottom of the center housing.
6. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.
7. Remove the nuts securing the turbocharger assembly to the exhaust manifold. Then, lift the turbocharger assembly away from the engine and place it on a bench.

8. Cover the end of the oil drain line, the oil outlet line, the air inlet and the exhaust outlet openings on the engine and turbocharger to prevent the entry of foreign material.

CAUTION:

The improper use of caustic chemicals may result in personal injury.

9. Clean the exterior of the turbocharger with a non–caustic cleaning solvent before disassembly.

6.4.3 Disassembly of Turbochargers

Disassemble the turbocharger as follows:

1. Mark the related positions of the compressor housing, center housing and turbine house with a punch or scribe to assure reassembly in the same relative position.

NOTICE:
Exercise care when removing the compressor housing and turbine housing to prevent damage to the compressor and turbine wheels.

2. Loosen the V–band coupling securing the compressor housing to the backplate assembly and remove the compressor housing and V–band.
3. Loosen the V–band coupling securing the turbine housing to the center housing. See Figure 6–12.

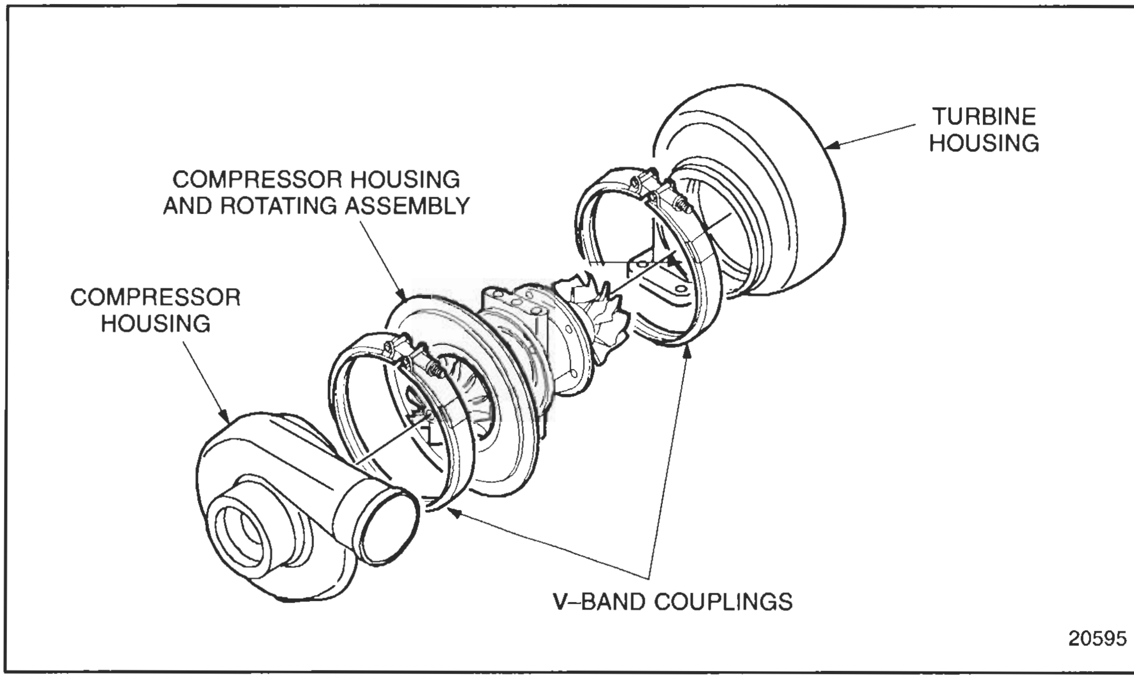


Figure 6–12 Series TV45 Turbocharger

4. Remove the turbine housing from the center housing.

6.4.3.1 Inspection and Cleaning of Turbocharger

Ceramic turbine wheels are extremely resistant to high temperatures, but at the same time are brittle. If debris is left in the air intake system, it may find its way through the engine and into the exhaust path. If large enough, these particles may cause turbine wheel chipping or "wheel burst."

NOTICE:
If the ceramic wheel becomes damaged or bursts, Detroit Diesel recommends replacing the exhaust system muffler if positioned in such a way that debris will fall back into the turbine housing. This precaution will prevent damage to the turbocharger at engine start–up.

Similar damage can result from a contaminated exhaust system. Any debris left in the exhaust system after service work can fall back into the exhaust wheel. If large enough, these particles may cause turbine wheel damage at initial engine startup. The exhaust manifold and exhaust piping attached to the turbocharger should also be inspected for debris and cleaned, if necessary, before being installed.

Any time the charge air cooler is removed, all charge air cooling system components *must* be inspected to make sure they are clean and free of any casting slag, core sand, welding slag, or any other contaminants that could break free during engine operation and damage the ceramic turbine wheel.

Inspect the disassembled turbocharger, discarding any damaged parts, in the following manner:

1. Visually check for nicked, crossed or stripped threads.
2. Visually check the turbine wheel shroud and turbine wheel for signs of rubbing.
3. Visually check the compressor wheel for signs of rubbing or damage from foreign material. The wheel must be free of dirt and other foreign material.

4. Check the bearing axial end play:

[a] Clamp the center housing assembly in a bench vise equipped with soft jaws. See Figure 6–13.

[b] Fasten the dial indicator and magnetic clamp, part of magnetic base dial indicator set, J 7872–2, to the center housing so that the indicator tip rests on the end of the rotating shaft on the compressor side. See Figure 6–13.

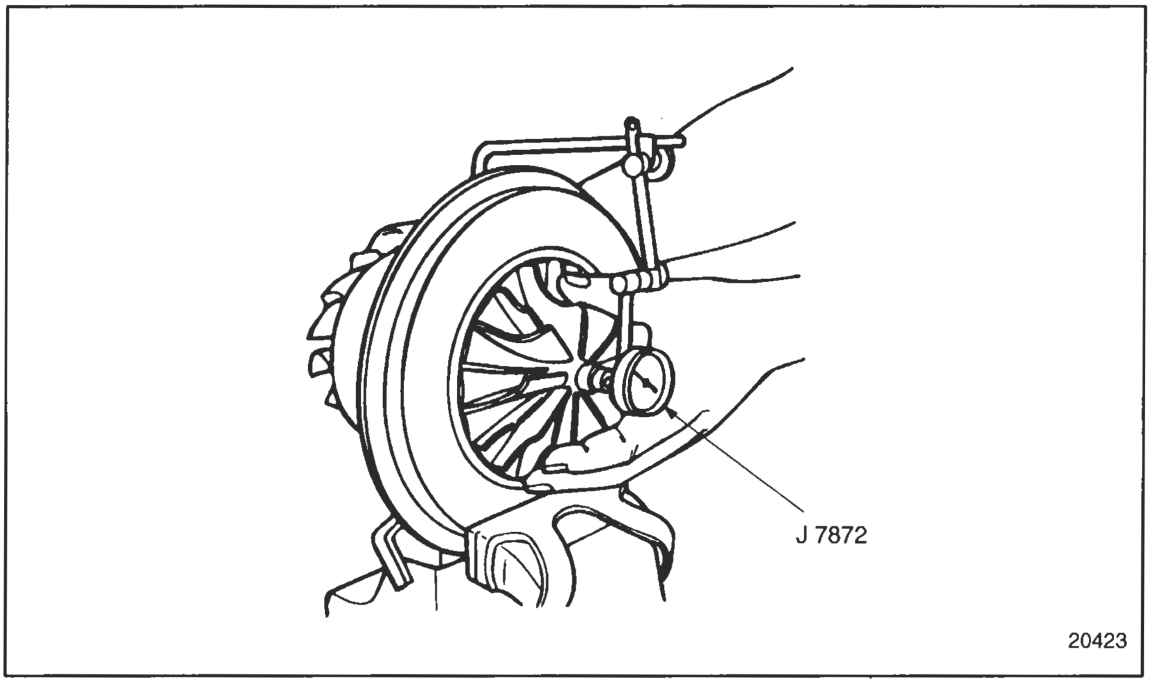


Figure 6–13 Checking Bearing Axial End Play

[c] Move the shaft axially back and forth by hand. The total indicator reading (thrust float) should be 0.0762–0.254 mm (.003 to .010 in.). If the total dial indicator readings do not fall within the specified limits, replace the rotating assembly.

5. Check the shaft radial movement as follows:

   [a] Install the turbo shaft checker, J 39164, to the oil drain opening of the center section. The special curved end of the tool must contact the wheel shaft through the oil outlet port and an internal opening in the center section casting. See Figure 6–14.

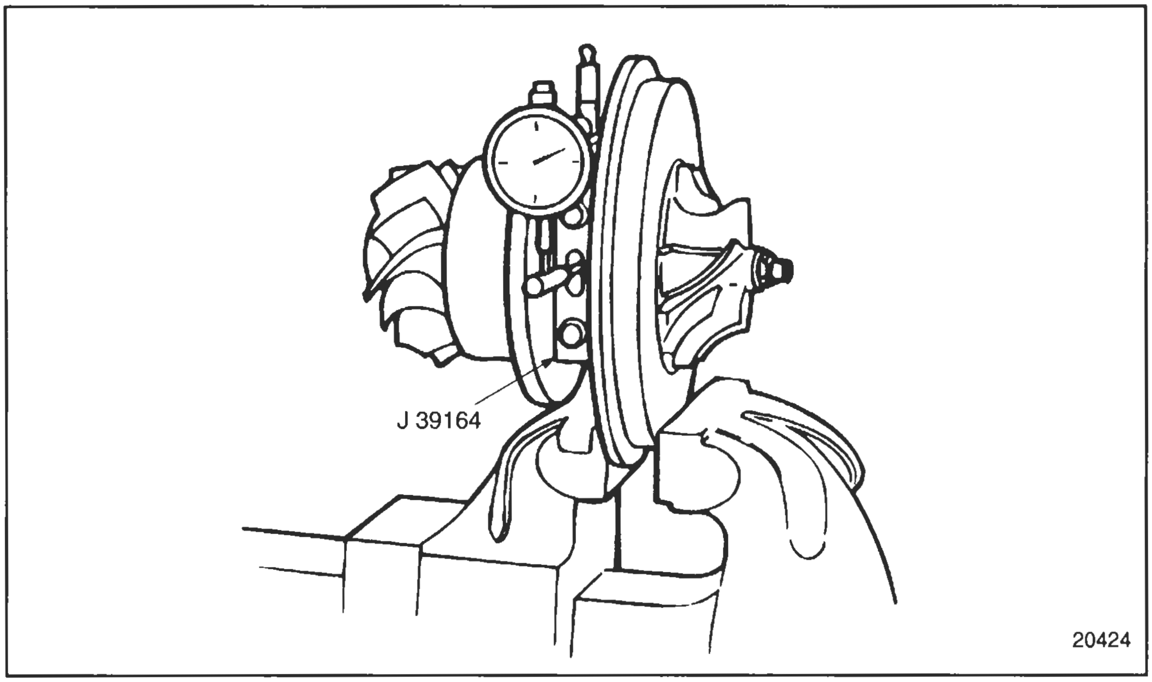


Figure 6–14 Checking Shaft Radial Movement

   [b] Install a dial indicator. See Figure 6–14.

   [c] Place the swivel adaptor, part of magnetic base dial indicator set, against the scribed line of the turbo shaft checker, J 39164.

   [d] Grasp each end of the rotating assembly and, applying equal pressure at each end, move the rotating shaft first toward and then away from the dial indicator, creating a transverse movement in the shaft. The total indicator reading (radial movement) should be .005 –.0065 in. (0.127–0.165 mm). If the total indicator readings do not fall within the specified limits, replace the rotating assembly.

6.4.4 Assembly of Turbocharger

Use the following procedure to assemble the turbocharger:

NOTICE:
As the parts are assembled, cover the openings to prevent entry of dirt or other foreign material, which may cause component damage.

1. Cover all openings.
2. Position the turbine housing as marked at disassembly against the center housing and secure it in place.

NOTICE:
Failure to properly orient the "T" bolt end of the clamp can result in an exhaust leak, turbine wheel damage or both.

3. Position the V–band coupling between the turbine housing and center housing so that the "T" bolt end does not interfere with the turbine housing. Then tighten the V–band coupling nut, as follows:
   [a] Lubricate the toggle bolt threads with a high temperature anti–seize compound.
   [b] Tighten the nut on the V–band toggle bolt to approximately 18 N·m (160 lb·in.) torque.

NOTE:
Do not pull a misaligned turbine housing into alignment with the V–band coupling. The parts must be aligned and seated first.

   [c] Loosen the V–band coupling nut to approximately 6 N·m (50 lb·in.) torque, then torque the nut to 12–15 N·m (106–130 lb·in.).

4. Position the compressor housing as marked at disassembly against the backplate assembly and secure it in place with the V–band coupling.
5. Lightly lubricate the threads of the toggle bolt with engine oil and tighten the nut to 12–15 N·m (106–130 lb·in.) torque.

6.4.5 Installation of Turbocharger

To install the turbocharger:

1. Attach a chain hoist and a suitable lifting sling to the turbocharger assembly.
2. Remove any covers that were placed over the openings of the air inlet and exhaust outlet openings on the engine and turbocharger when the turbocharger was removed.
3. Remove any covers on the oil inlet and drain lines, and the oil inlet and drain openings on the turbocharger.
4. Place the turbocharger assembly into position on the exhaust manifold. Use a new gasket between the exhaust manifold and the turbine housing flange.
5. Secure the turbocharger to the exhaust flange. Tighten the nuts just enough to hold the turbocharger in place.
6. Slide the charge air cooler air inlet tube hose over the compressor housing outlet opening and secure it in place with the hose clamps.

CAUTION:

Do not use any type of lubricant on the inside of any air inlet hose or on the hose contact surfaces of the turbocharger compressor housing, CAC ducting or the intake manifold. Use of lubricant can cause the hose to blow off when the turbocharger builds boost.

7. Tighten the turbocharger to exhaust manifold locknuts to 58–73 N·m (43–54 lb·ft) torque.
8. Install the oil drain line, using a new gasket, between the opening in the bottom side of the turbocharger center housing and the drain hose that runs to the cylinder block. Tighten the bolts to 30–38 N·m (22–28 lb·ft) torque.
9. Refer to section 11.1.3 for verification of proper turbocharger installation.

6.5 CHARGE AIR COOLER

A CAC is normally mounted ahead of the cooling system radiator. The compressed air leaving the turbocharger is directed through the charge air cooler before it goes to the air inlet side of the intake manifold. See Figure 6–15.

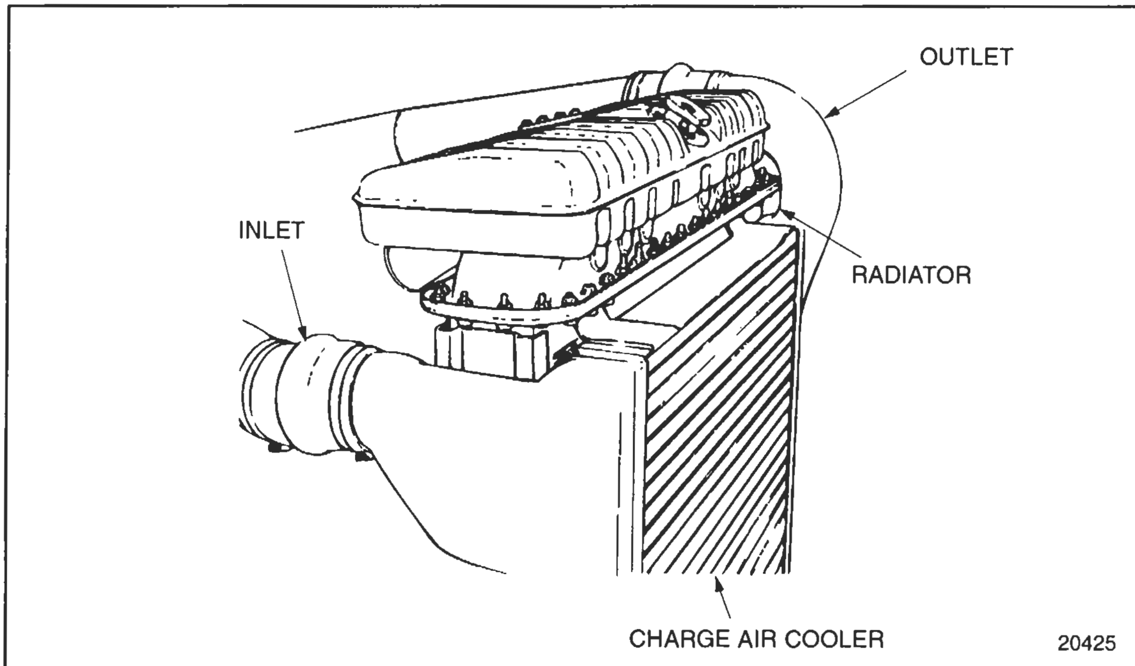


Figure 6–15 Typical Charge Air Cooler

The CAC is used to reduce the temperature of the compressed air leaving the turbocharger before it reaches the intake manifold. This permits a more dense charge of air to be delivered to the engine.

Cooling is accomplished by incoming air flowing past the tubes and fins of the intercooler. The compressed intake charge flowing inside the CAC core transfers the heat to the tubes and fins where it is picked up by the incoming outside air. See Figure 6–16.

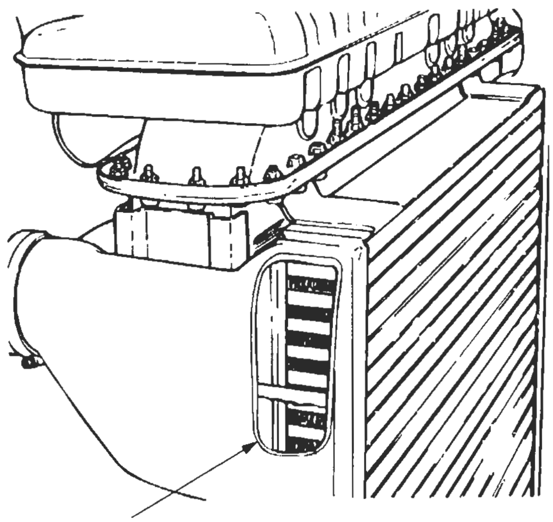
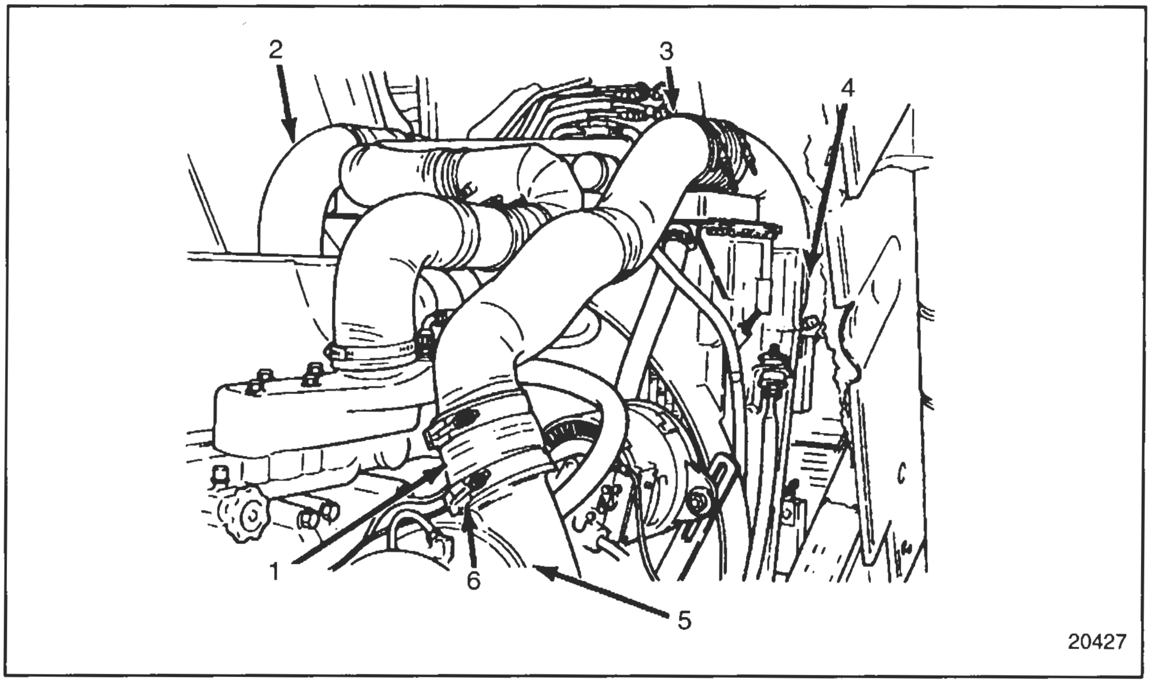


Figure 6–16 Charge Air Cooler Cross–section

Metal ductwork is used to transfer the air from the turbocharger outlet to the CAC, and from there to the intake manifold. See Figure 6–17.

Flexible rubber couplings and hose clamps are used to secure the ductwork to the turbocharger, the CAC inlet and outlet, and the intake manifold.



1. Flexible Coupling
2. CAC Outlet Duct
3. CAC Inlet Duct
4. Charged Air Cooler (CAC)
5. Turbocharger
6. Coupling Hose Clamp

Figure 6–17 Charge Air Cooler and Related Parts

6.5.1 Repair or Replacement of Charge Air Cooler

Refer to the OEM guidelines to for CAC repair and replacement procedures.

6.5.2 Cleaning and Removal of Charge Air Cooler

Refer to the OEM guidelines for CAC service procedures.

6.5.2.1 Inspection of Charged Air Cooler

After a turbocharger failure, inspect charged air cooler as follows:

CAUTION:
To avoid possible personal injury, charged air cooler damage, or both while cleaning or inspecting, observe all NOTICES, CAUTIONS, WARNINGS, etc. provided by the cooler manufacturer and the OEM.

1. Remove all the piping to and from the charged air cooler and the air intake manifold.

NOTICE:
If the charged air cooler is contaminated with metal particles resulting from a damaged turbocharger, it *must* be replaced with a new charged air cooler. Any debris left in the charged air cooler, especially metal particles, can cause severe engine damage.

2. Inspect all parts carefully for metal and oil contamination.

If the charged air cooler is contaminated with engine oil, contact the vehicle OEM and obtain the charged air cooler manufacturer's recommendations on cleaning and inspection.

3. Remove and inspect the air intake manifold for any accumulation of oil. Remove the oil from the manifold and from the area above the valves before replacing the charged air cooler system.

NOTICE:
Failure to remove residual lubricating oil from air intake passages may allow the oil to act as an external fuel source at engine startup. This can cause a sudden engine overspeed condition, which may result in severe engine damage.

4. Remove the oil from the manifold and from the area above the valves before replacing the charged air cooler system.

6.5.3 Installation of Charge Air Cooler

Refer to the OEM guidelines for CAC installation procedures.

6.6 AIR DRYER

Refer to OEM guidelines for air dryer for repair or replacement procedures.

6.A ADDITIONAL INFORMATION

SPECIFICATIONS

This section contains the exceptions to the fastener torque specifications.

Torque Specification Exceptions – Fasteners

The proper bolt and nut torque is dependent on its size. The proper torque for metric nuts and bolts are listed in Table 6 in the "General Information" section at the beginning of this manual. The exceptions to this rule are listed in Table 6–1. Standard (nonmetric) nut and bolt torque specifications are listed in Table 5 in the "General Information" section at the beginning of this manual.

Bolt and Size	Torque, N·m	Torque, lb·in.
M5 X 30.0 mm	2.37–2.94	21–26

Table 6–1 Exceptions – Metric Fastener Torque Specifications

NOTE:
The turbo–boost pressure sensor retaining bolts are M5 x 30.0 mm long.

SERVICE TOOLS

Listed in Table 6–2 are the service tools used in this section.

Tool Number	Tool Name
J 36571	Surface Conditioning Set
J 39164	Turbo Shaft Checker
J 7872	Magnetic Base Dial Indicator Set

Table 6–2 Service Tools

7 EXHAUST SYSTEM

7.1 OVERVIEW OF EXHAUST SYSTEM

The engine is equipped with a single-piece exhaust manifold. See Figure 7-1.

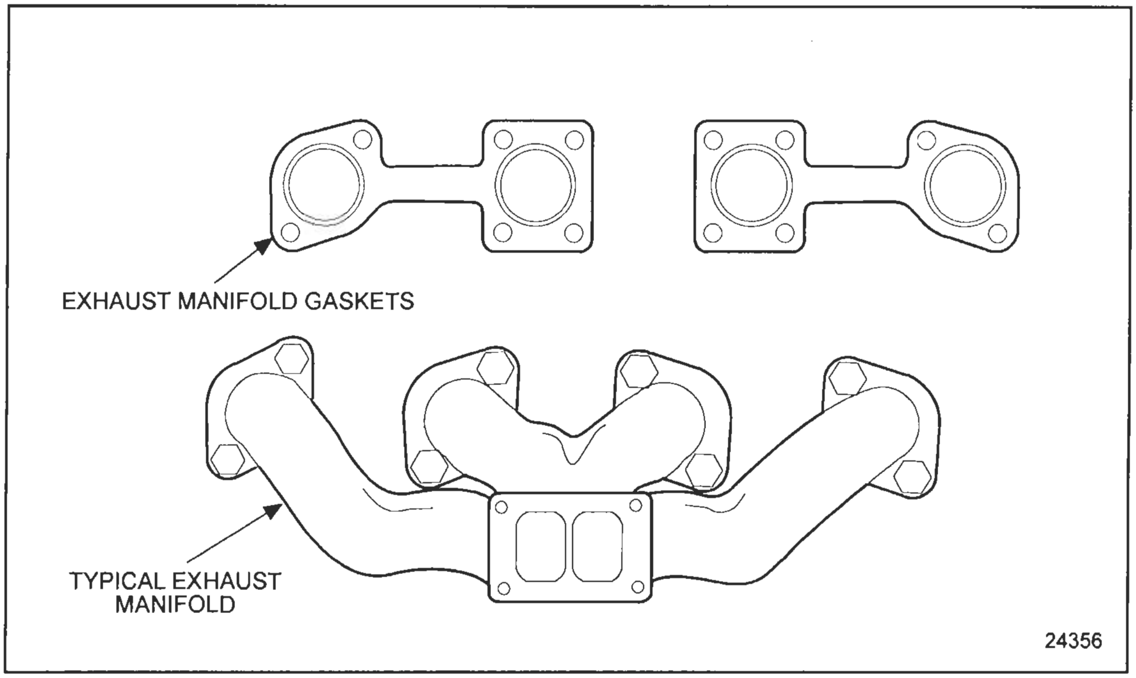


Figure 7-1 Exhaust Manifold Gaskets and Related Parts

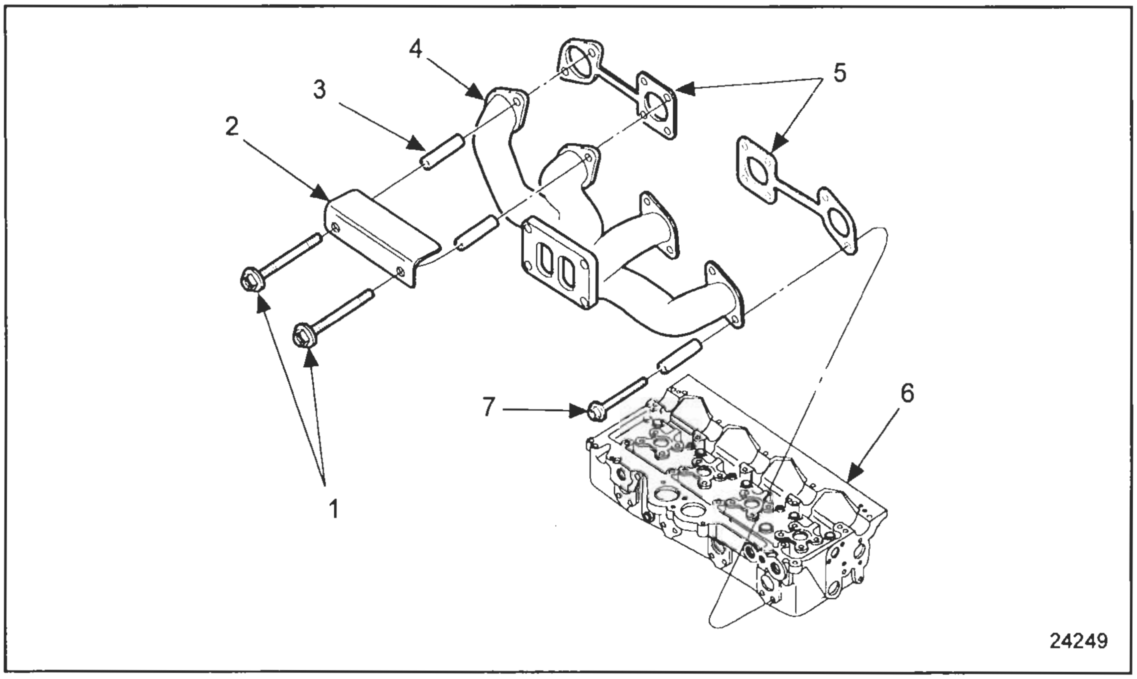
The outlet flange is centrally located and connects directly to the turbocharger turbine housing.

The exhaust manifold is attached to the cylinder head with eight specially hardened bolts.

Spacers are used between the bolt head and exhaust manifold.

7.2 EXHAUST MANIFOLD

The cast-iron exhaust manifold is attached to the cylinder head with eight special alloy hardened bolts and eight bolt spacers. The manifold has a square outlet flange which is bolted directly to the turbocharger turbine housing. See Figure 7-2.



1. Stud
2. Heat Shield
3. Spacers
4. Exhaust Manifold
5. Exhaust Manifold Gasket
6. Cylinder Head
7. Bolt

Figure 7–2 Typical Exhaust Manifold Mounting

Two identical exhaust manifold gaskets are used between the manifold and the cylinder head. See Figure 7-1.

7.2.1 Repair or Replacement of the Exhaust Manifold

To determine if repair is possible or replacement is necessary, perform the following procedure. See Figure 7–3.

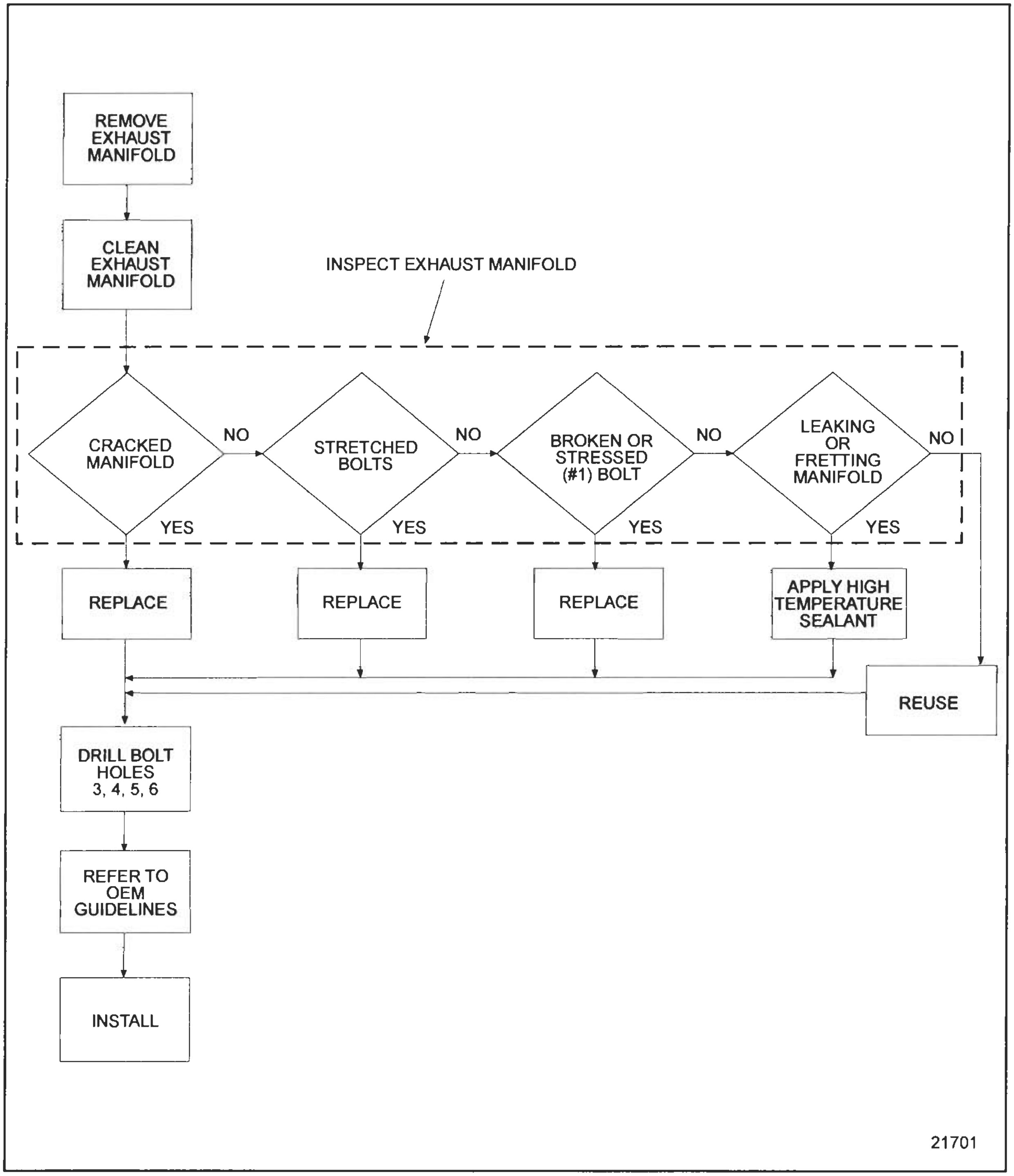


Figure 7–3 Flowchart for Repair or Replacement of Exhaust Manifold

7.2.2 Cleaning and Removal of the Exhaust System

Precleaning is not necessary.

Remove the exhaust manifold as follows:

1. Remove the turbocharger assembly. Refer to section 6.4.2.
2. Remove the eight bolts and spacers that secure the exhaust manifold to the cylinder head.
3. Remove the manifold. Discard the two gaskets.

Clean the exhaust manifold prior to inspection as follows:

1. Remove any loose scale and carbon that may have accumulated on the internal walls of the manifold.
2. Clean the manifold exterior with a wire brush.

7.2.2.1 Inspection of the Exhaust Manifold

Inspect the exhaust manifold as follows:

1. Inspect the exhaust manifold for damage.
   [a] Check the exhaust manifold for cracks, especially in the bolt clamp areas.
   [b] If manifold is cracked, replace with a new manifold.
2. Inspect manifold mounting bolts for damage.
   [a] Visually check for bolt stretching and thread damage.
   [b] If bolts are excessively stretched, or if threads are excessively damaged, replace with new bolts.

7.2.3 Installation of Exhaust Manifold

Install the exhaust manifold as follows:

1. Install four exhaust manifold guide studs, J 36107 into the cylinder head to position and hold the two exhaust manifold gaskets correctly, and facilitate installation of the manifold.
2. Install the exhaust gaskets (2) to the guide studs.
3. Install the assembled manifold to the guide studs.
4. Install four of the bolts and spacers to the vacant holes. Tighten the bolts finger tight.
5. Remove the four guide studs.
6. Install the remaining four manifold bolts and spacers to the holes from which the studs were removed.
7. Torque the bolts to 58–73 N·m (43–54 lb·ft) torque using the tightening sequence. See Figure 7–4.

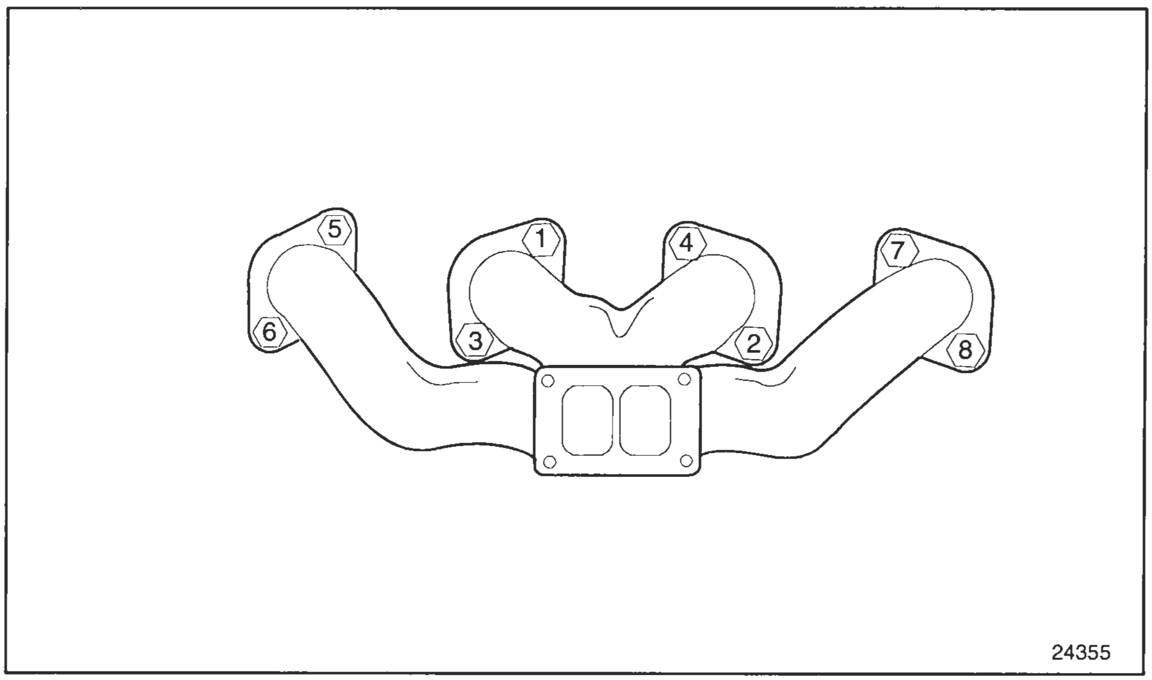


Figure 7–4 Exhaust Manifold Bolt Tightening Sequence

8. Install the turbocharger assembly. Refer to section 6.4.5.
9. Install any other equipment that was removed for this procedure.

CAUTION:

To avoid personal injury, ensure that the vehicle is parked on a level surface and the wheels are properly blocked before running engine.

10. Run the engine until normal operating temperature is reached.
11. Retorque the bolts to 73 N·m (54 lb·ft). See Figure 7–4.
12. Refer to section 11.3.6 for verification of proper exhaust manifold installation.

7.A ADDITIONAL INFORMATION

SERVICE TOOLS

Listed in Table 7–1 are the service tools used in this section.

Tool Number	Tool Name
J 36107	Guide Studs

Table 7–1 Tools Used to Service the Exhaust System

8 ELECTRICAL EQUIPMENT

8.1 OVERVIEW OF ELECTRICAL SYSTEM

The electrical system consists of the following components:

- Starting motor
- Battery-charging generator (alternator)
- Transistorized voltage regulator (normally integral to the alternator)
- Storage battery(s)
- Ignition switch
- Starting motor relay

CAUTION:

With the exception of the DDEC system, never attempt to service any engine electrical systems until the batteries have been disconnected. When working on the alternator, be careful not to come in contact with the exhaust manifold or turbocharger. These components may be hot.

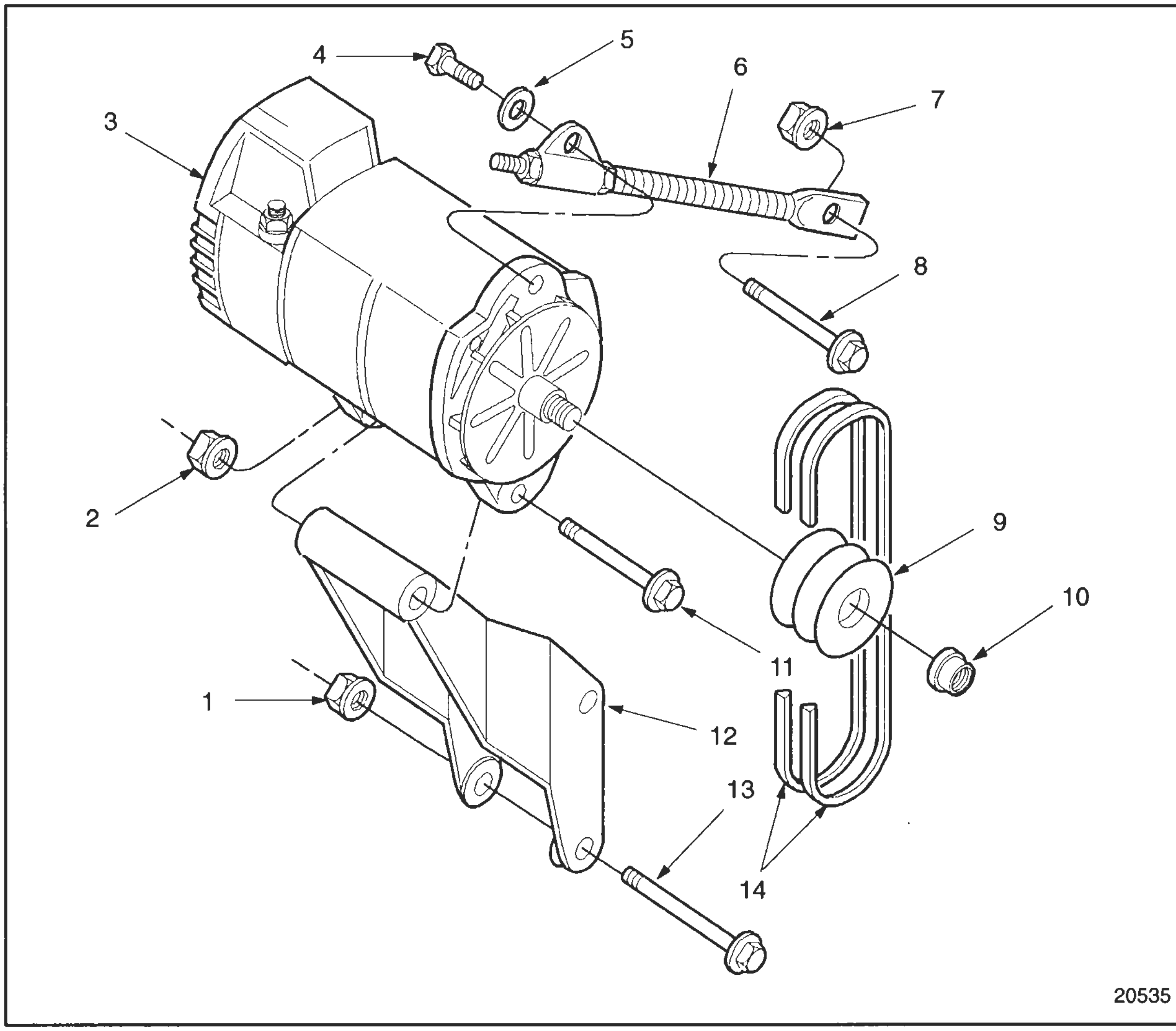
Detailed information on the maintenance and repair of the specific types of electrical equipment can be found in the service manuals and bulletins issued by the OEM. Information regarding equipment manufactured by the Delco-Remy Division of General Motors Corporation may be obtained from their electrical equipment operation and service manuals. The manuals may be obtained from an AC-Delco service outlet, or from the Technical Literature Section, Delco-Remy Division of General Motors Corporation, Anderson, Indiana.

In most instances, repairs and overhaul work on electrical equipment should be referred to an authorized repair station of the original equipment manufacturer. With the exception of DDEC components, replacement parts for electrical equipment should be ordered through the original equipment manufacturer's outlets, since these parts are not normally supplied with the engine. For electrical equipment manufactured by Delco-Remy Division, service and parts are available through AC-Delco branches and repair stations.

8.2 BATTERY CHARGING ALTERNATOR

The battery charging alternator provides a source of electrical current for maintaining the storage battery in a charged condition and supplies sufficient current to carry any other electrical load requirements up to the rated capacity of the alternator.

The battery charging circuit consists of an alternator, a voltage regulator, a battery(s) and the connecting wiring. See Figure 8–1, for parts of the battery charging alternator.



1. Nut (2)
2. Nut
3. Alternator
4. Bolt, Alternator–to–Adjusting Rod
5. Washer
6. Alternator Adjusting Rod
7. Nut
8. Bolt, Adjusting Rod–to–Engine
9. Pulley, Alternator Drive
10. Locknut
11. Bolt, Alternator–to–Mounting Bracket
12. Mounting Bracket
13. Bolt, Mounting Bracket–to–Engine (2)
14. Drive Belts

Figure 8–1 Typical Alternator and Related Parts Location

The alternator used on the Series 50 automotive engine is a hinge-mounted, alternating current (AC), self-rectifying unit. See Figure 8-2.

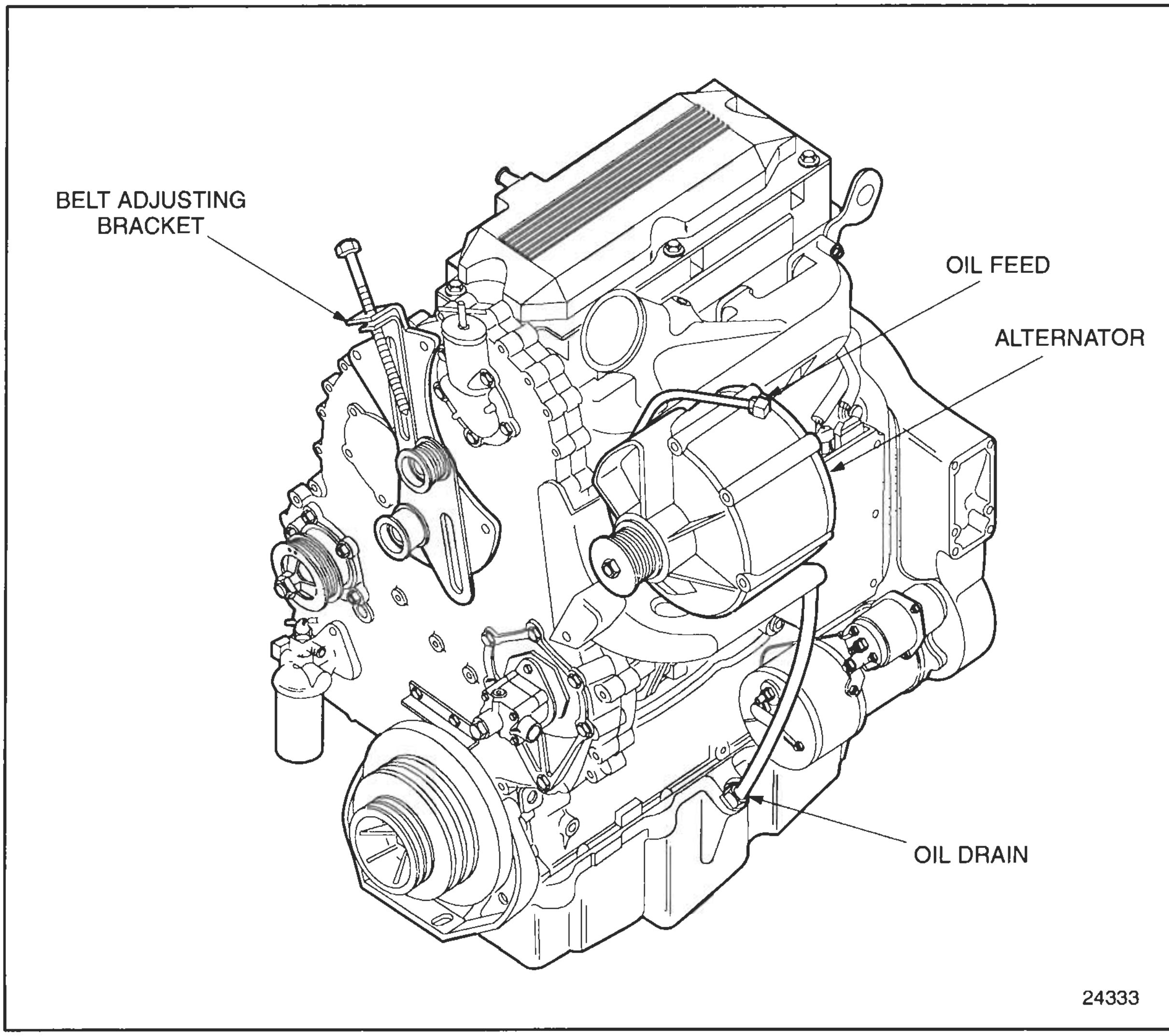


Figure 8–2 Series 50 Coach Alternator Mounting

On engines equipped with the SI series Delco-Remy alternators, the voltage regulator is typically electronic and is located inside the alternator. Refer to the appropriate manufacturer's service instructions for complete regulator and alternator servicing information.

The Series 50 alternator is front mounted and belt driven using the accessory drive pulley. The accessory drive pulley is gear driven by the bull gear. Refer to section 1.28 for accessory drive information.

8.2.1 Replacement of Alternator

Refer to the OEM guidelines for alternator service procedures.

8.2.2 Cleaning and Removal of Alternator

Precleaning is not necessary.

Remove the alternator as follows:

CAUTION:

With the exception of the DDEC system, never attempt to service any engine electrical systems until the batteries have been disconnected. When working on the alternator, be careful not to come in contact with the exhaust manifold or turbocharger. These components may be hot.

1. Disconnect the cables at the batteries.
2. Tag each lead to ensure correct connection when the alternator is reinstalled.
3. If the alternator has more than the output cable lead, disconnect all other leads from the alternator, and tag each one to ensure correct installation.
4. Remove the alternator output cable.
5. Loosen the alternator mounting bolts and adjusting rod nut to allow slack in the drive belts.
6. Remove the drive belts.
7. While supporting the alternator, remove the adjusting rod bolt and hardened washer.
8. Loosen and remove the nut and washer at the rear alternator mounting flange.
9. While supporting the alternator, remove the alternator–to–bracket bolt to prevent it from falling.
10. Remove the alternator carefully to prevent damage.
11. Remove and retain the alternator pulley locknut, alternator pulley, and fan from the unit.

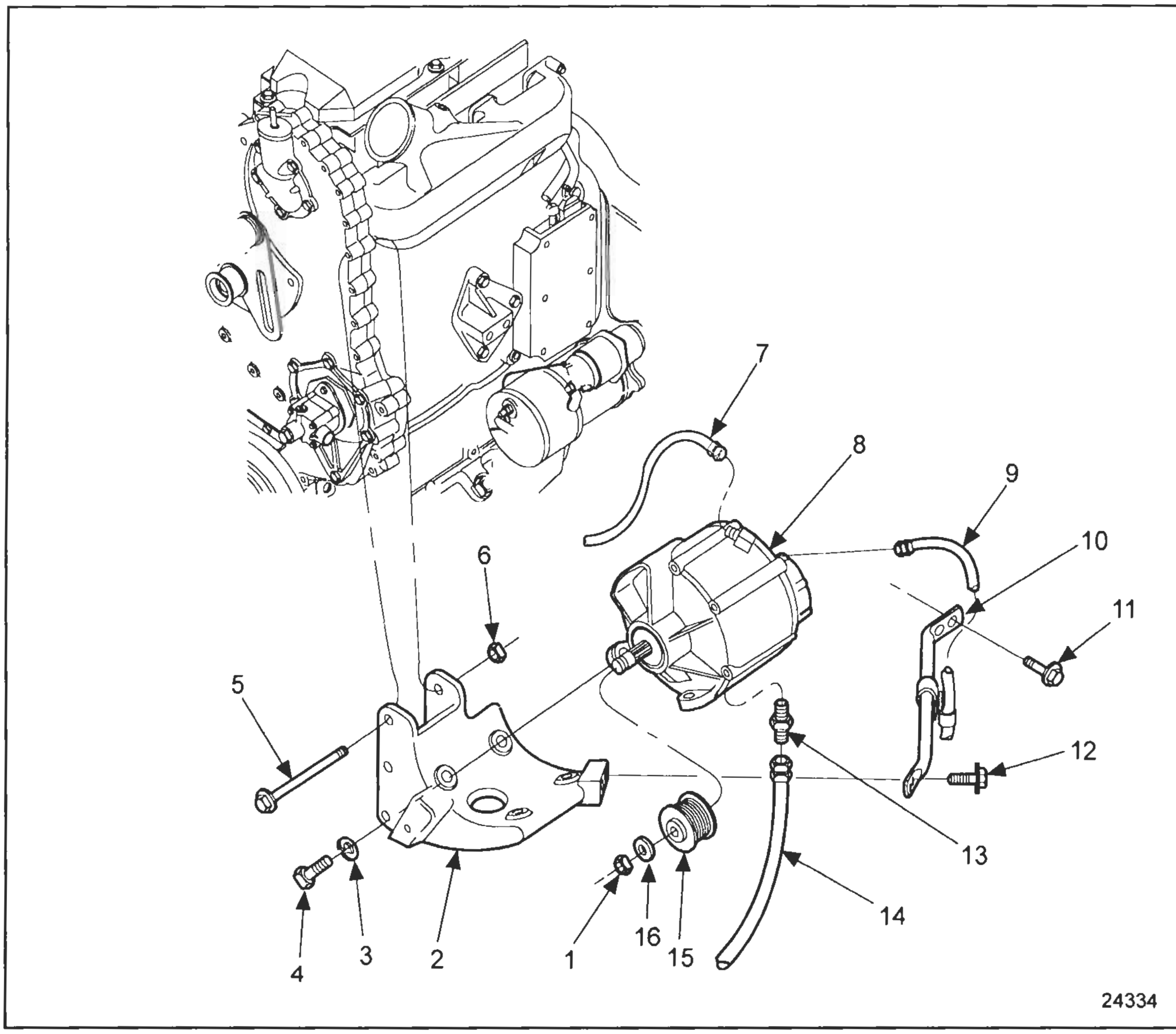
8.2.2.1 Inspection of Alternator

Refer to OEM guidelines for alternator service procedures.

8.2.3 Installation of Alternator

Install alternator as follows:

1. Install alternator mounting bracket, see Figure 8-3, if removed, to the gearcase. Torque the mounting bolts to 58-73 N·m (43-54 lb·ft).



1. Pulley Nut
2. Alternator Mounting Bracket
3. Washer
4. Bolts, Bracket to Alternator (3)
5. Bolt, Bracket to Front Cover
6. Nut (3)
7. Alternator Vent Hose
8. Alternator
9. Oil Supply Tube
10. Alternator Bracket Support
11. Support Bolt to Block
12. Bracket Support Bolt
13. Oil Drain Tube Connector
14. Oil Drain Tube
15. Alternator Pulley
16. Washer

Figure 8–3 Series 50 Coach Alternator and Related Parts

2. Install the fan, drive pulley and locknut, if removed, to the alternator. Tighten the pulley retaining nut to 95–108 N·m (70–80 lb·ft) torque.
3. If the pulley was not removed, check the retaining nut for proper torque. Torque the retaining nut to 95–108 N·m (70–80 lb·ft), as necessary.
4. Position the alternator on the mounting bracket, and align the holes in the alternator mounting flanges with the tube in the bracket.

NOTE:
There are two holes in the front alternator end frame mounting flanges. One is threaded and one is not threaded. The threaded hole is positioned up and is used to secure the alternator to the adjusting rod.

5. Install the alternator–to–bracket bolt and locknut. Insert the adjusting rod bolt, with washer installed, through the adjusting rod bracket and into the threaded hole in the alternator end frame. Tighten both bolts finger tight.
6. Install the drive belts in the grooves of the alternator and accessory drive pulleys. See Figure 8–4.

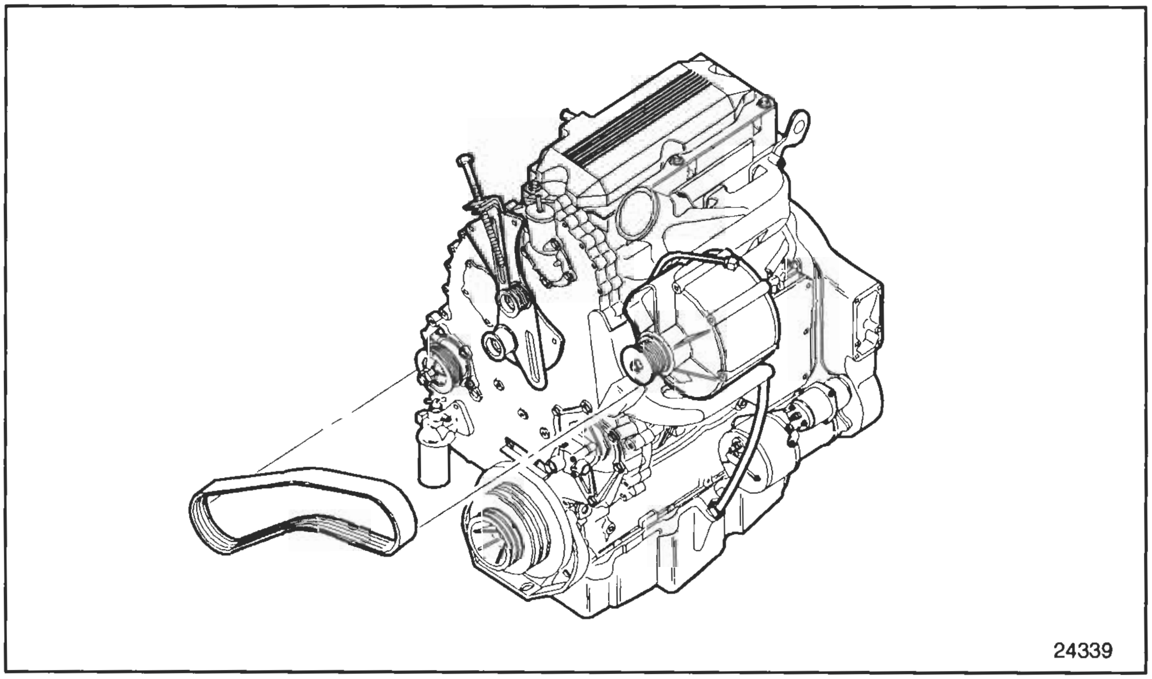


Figure 8–4 Coach Poly–vee Belt Installation

7. Adjust the alternator belt tension. Refer to section 13.5.7.
8. Tighten the alternator–to–mounting bracket bolt and nut and the alternator–to–adjusting rod bracket bolt to 81–95 N·m (60–70 lb·ft) torque.
9. Attach the wires and cables to the alternator. Be sure that each one is correctly installed in the location from which it was removed. Keep all connections clean and tight.

8.2.3.1 Checking Alternator Belt Tensioning

The recommended tension for a new belt is 300 lb (1.33 kN). However, because a new belt loses tension rapidly during the first few minutes of operation, it is important to check the tension after running the engine for 10 to 15 minutes. To check belt tension, use the following procedure procedure:

1. Tension the new drive belt to 300 lb (1.33 kN) using Kent–Moore belt tension gauge, J 41251, or equivalent.
2. Start and run the engine from 10 to 15 minutes to allow the belt to warm up and seat in the pulley grooves.
3. Stop the engine, and allow it to cool for 10 to 15 minutes.
4. Measure belt tension:
   [a] If tension is 200 lb (0.89 kN) or more, no retensioning is required.
   [b] If tension is less than 200 lb (0.89 kN), retension the belt to 200 lb (0.89 kN).

8.3 STORAGE BATTERY

The lead–acid storage battery is an electro–chemical device for storing energy and converting chemical energy into electrical energy.

The battery has three major functions:

- It provides a source of current for starting the engine.
- It acts as a stabilizer to the voltage in the electrical system.
- It can, for a limited time, furnish current when the electrical demands exceed the output of the alternator.

CAUTION:

Explosive gas may remain in or around the battery for several hours after it has been charged. Sparks or flames can ignite this gas causing an internal explosion which could shatter the battery. Flying pieces of the battery structure and electrolyte splash can cause personal injury. Battery electrolyte is acid. Extreme care should be exercised to avoid skin or eye contact with the electrolyte.

If you come in contact with battery electrolyte:

1. Flush your skin with water.
2. Apply baking soda or lime to help neutralize the acid.
3. Flush your eyes with water for 10–15 minutes.
4. Get medical attention immediately.

In the selection of a replacement battery, it is always good practice to select one of an "electrical size" at least equal to the battery originally engineered for the particular equipment by the manufacturer. This information is listed in Table 8–1.

Series 50 Engine	System Voltage	Minimum Battery Rating [SAE Cold Cranking AMPS (CCA) at –17.8°C (0°F)]
8.5 Liter	12V	1875 CCA*
8.5 Liter	24V	950 CCA*

* Recommendation based on the use of Delco–Remy 42MT (or equivalent) cranking motor.

Table 8–1 Electrical Size of Series 50 Replacement Battery

8.3.1 Repair or Replacement of Storage Battery

Refer to the OEM for service procedure.

8.3.2 Cleaning and Removal of Storage Battery

Precleaning may be necessary. Refer to OEM guidelines.

Remove storage battery as follows:

1. Disconnect grounded terminal of the battery.
2. Remove the cable clamps.
3. Remove felt washer.
4. Remove the battery.

8.3.2.1 Inspection of Storage Battery

For storage battery inspection procedure, refer to OEM guidelines.

8.3.3 Installation of Storage Battery

Install the battery as follows:

1. Clean battery carrier, as necessary.
2. Seat the battery level in its carrier.

NOTICE:
Do not draw the hold–down clamps down too tightly or the battery case will become distorted or crack.

3. Tighten the hold–down clamps evenly until snug.
4. Attach the cable clamps after making sure the cables and terminal clamps are clean and in good condition.
5. Place a new felt washer at the base of each terminal beneath the cable clamps, to make the cable connections as corrosion resistant as possible.
6. Coat the entire connection with a heavy general–purpose grease.

NOTE:
Be sure the ground cable is clean and tight at the engine block or frame.

NOTICE:
Connect the **grounded** terminal of the battery **last** to avoid short circuits, which will damage the battery.

7. Check the polarity to be sure the battery is not reversed with respect to the generating system.
8. Refer to section 11.1.8 for verification of proper storage battery installation.

8.4 CRANKING MOTOR

The cranking motor is bolted to the flywheel housing. See Figure 8–5.

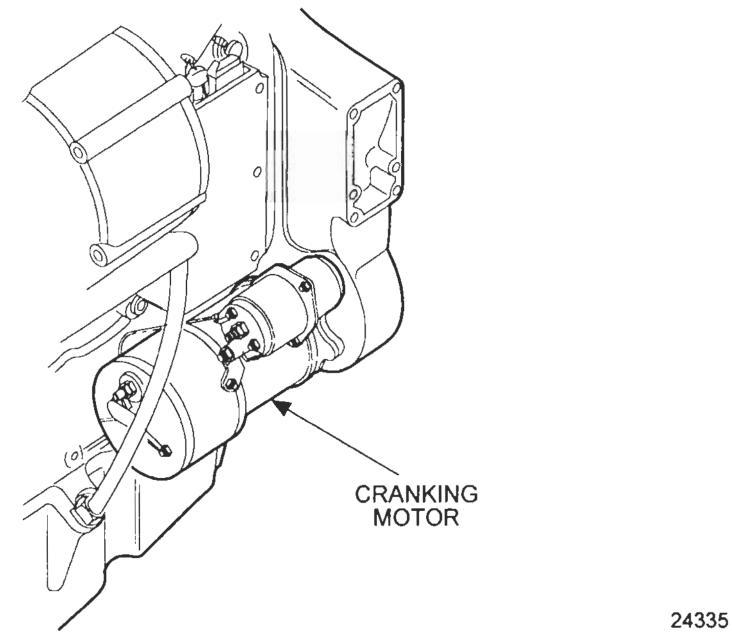


Figure 8–5 Cranking Motor Mounting

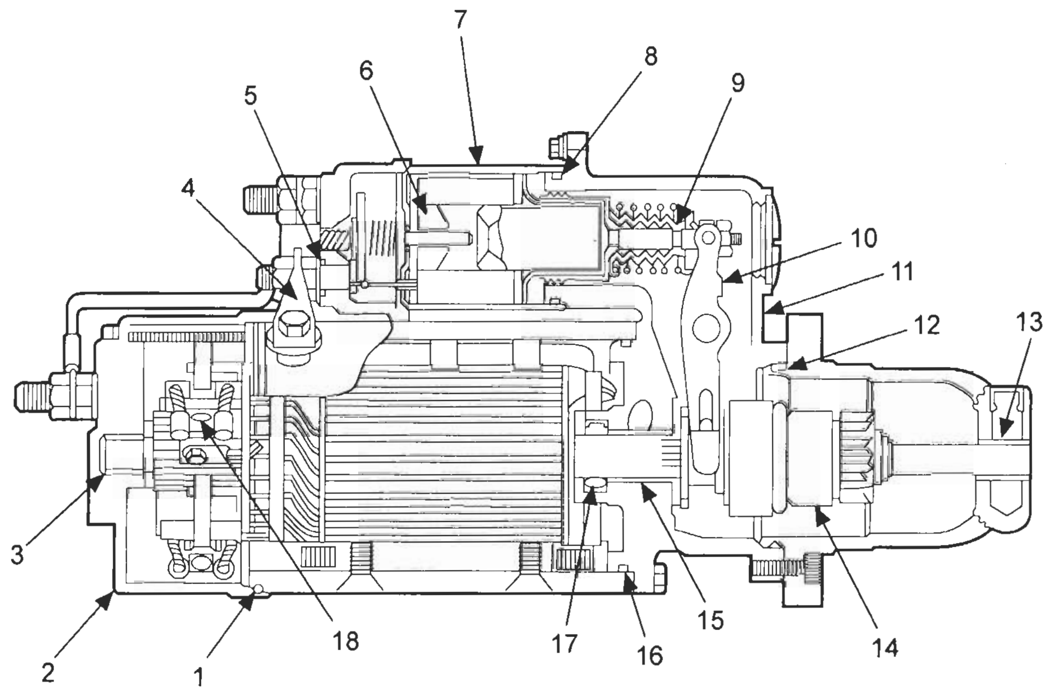
NOTICE:
To prevent excessive overrun and damage to the drive and armature windings, the switch should be opened immediately when the engine starts. A cranking period should not exceed 30 seconds without stopping to allow the motor to cool for at least two minutes.

When the cranking circuit is closed, a drive pinion on the armature shaft engages with the teeth on the engine flywheel ring gear to crank the engine. When the engine starts, it is necessary to disengage the drive pinion to prevent the armature from overspeeding and damaging the cranking motor. To accomplish this, the cranking motor is equipped with an overrunning clutch within the drive pinion. The cranking motor drive pinion and the engine flywheel ring gear must be matched to provide positive engagement and to avoid clashing of the gear teeth.

NOTE:
Some engines may be equipped with air starters. Contact starter manufacturer for operating characteristics and rebuilding procedures.

The 42 MT cranking motor typically used on the Series 50 engine has a nose housing that can be rotated to obtain a number of different solenoid positions with respect to the mounting flange. The commutator end cap can be removed to inspect the brushes, in most cases, without removing the cranking motor from the vehicle.

The cranking motor armature is supported by three sintered bronze bearings located, one each, in the nose and intermediate housings, with one in the commutator end cap. See Figure 8-6.



1.	O–ring	10.	Shift Mechanism (Totally Enclosed)
2.	End Cap (Removal for Inspection)	11.	Two–piece Housing
3.	Bronze Bearing	12.	O–ring
4.	Connector Strap	13.	Bronze Bearing
5.	Gasket	14.	Heavy–duty Drive Overrunning Clutch
6.	Low Friction Bushing	15.	Bronze Bearing
7.	Seamless, One–piece Solenoid Case	16.	O–ring
8.	O–ring	17.	Shaft Seal
9.	Sealing Boot	18.	One–piece Brush

Figure 8–6 Typical Cranking Motor Cross–section

Sintered bronze bearings used in the current cranking motors have a dull finish, compared to the former machined, cast bronze bearings, which had a shiny finish.

The cranking circuit may contain a key start switch or push switch (or both), a relay, magnetic switches, solenoids, oil pressure switch, fuel pressure switch, and other protective devices. For the complete cranking circuit, refer to the vehicle manufacturer's wiring diagram.

A basic cranking circuit is shown in the following illustration. See Figure 8-7.

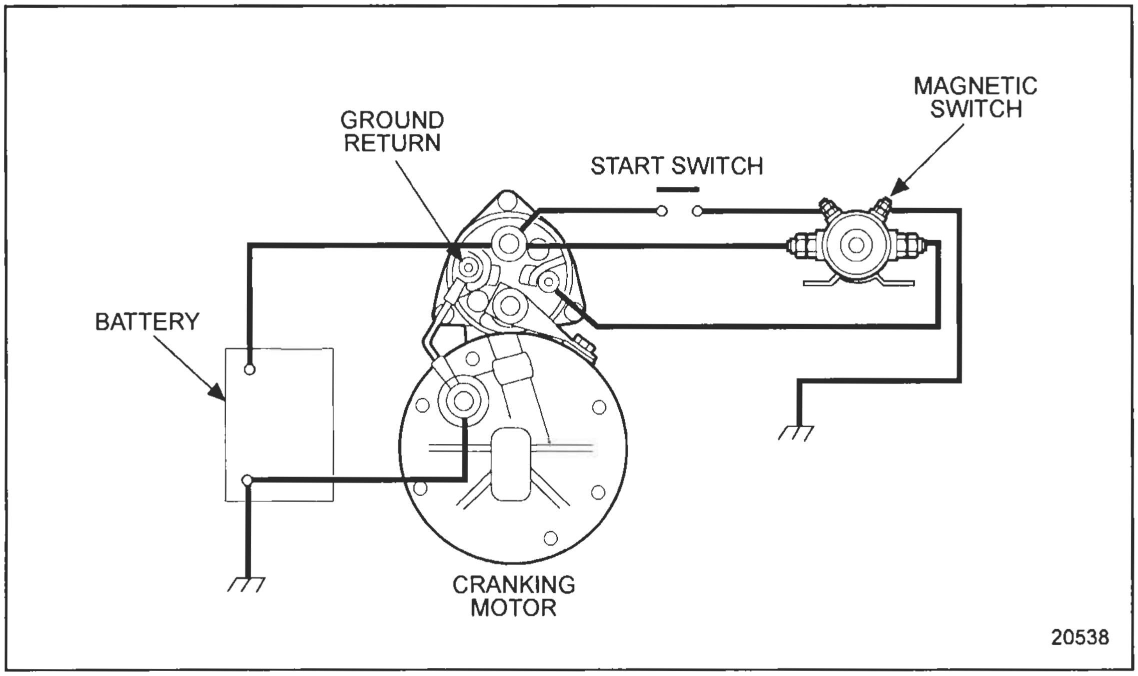


Figure 8–7 Basic Cranking Circuit

A solenoid, mounted on the cranking motor housing, operates the overrunning clutch drive by linkage and a shift lever. When the start switch is closed, the magnetic switch contacts close, and the solenoid windings are connected to the battery. The resulting plunger and shift lever movement causes the pinion to engage the engine flywheel ring gear and the solenoid main contacts to close, and the cranking takes place.

8.4.1 Replacement of Cranking Motor

Refer to the OEM guidelines for cranking motor service procedures.

8.4.2 Cleaning and Removal of Cranking Motor

Precleaning is not necessary.

Remove the cranking motor as follows:

CAUTION:
Never attempt to service engine electrical systems (except DDEC) until the batteries have been disconnected.

1. Remove the ground strap or negative cable(s) from the battery(s).
2. Tag each lead to ensure correct connections when the cranking motor is reinstalled.
3. Disconnect the cranking motor cables and solenoid wiring.
4. Support the motor, and remove the three bolts which secure it to the flywheel housing.
5. Pull the motor out to remove it from the flywheel housing.

If the nose housing requires relocation, perform the following steps:

NOTICE:
The solenoid should not be located below the centerline of the cranking motor. Dust, oil, moisture and foreign material can collect and cause solenoid failure.

1. Remove the six socket head screws (1 short and 5 long) and six neoprene plugs from the unused holes if a twelve-hole mounting flange is used.
2. Turn the nose housing to the required position.
3. Install the six socket head screws, with the short screw in the shallow hole nearest the solenoid and six neoprene plugs, if a twelve hole mounting flange is used.
4. Tighten the screws to 18–23 N·m (13–17 lb·ft) torque.

8.4.3 Installation of Cranking Motor

Install the cranking motor as follows:

CAUTION:

Never attempt to service engine electrical systems (except DDEC) until the batteries have been disconnected.

1. Support the cranking motor, and install the three bolts that secure it to the flywheel housing.
2. Connect the cranking motor cables and the solenoid wiring.
3. Install the ground strap or negative cable(s) to the battery(s).
4. If aluminum flywheel housing is used, tighten the cranking motor attaching bolts to 187–209 N·m (138–154 lb·ft) torque. If a cast iron flywheel housing is used, the cranking motor attaching bolts should be tightened to 245–306 N·m (181–226 lb·ft) torque.
5. If equipped with a 42 MT, install wiring terminal leads to the cranking motor and the solenoid switch.
6. Tighten the smaller connections to 1.8–3.4 N·m (16–30 lb·in.) torque. Tighten the larger connections to 27–34 N·m (20–25 lb·ft) torque.

NOTE:
Keep all of the electrical connections clean and tight.

7. Refer to section 11.2 for verification of proper cranking motor installation.

8.A ADDITIONAL INFORMATION

SPECIFICATIONS

This section contains the exceptions to the fastener torque specifications.

Torque Specification Exceptions – Fasteners

The proper bolt and nut torque is dependent on its size. The proper torque for metric nuts and bolts are listed in Table 6 in the "General Information" section at the beginning of this manual. The exceptions to this rule are listed in Table 8–2. Standard (nonmetric) nut and bolt torque specifications are listed in Table 5 in the "General Information" section at the beginning of this manual.

EXCEPTIONS TO STANDARD FASTENER TORQUE SPECIFICATIONS

Fastener	Torque, N·m	Torque, lb·ft
Bolt, Alternator Mounting Bracket	58–73	43–54
Nut, Drive Pulley	95–108	70–80
Bolt, Alternator–to–Mounting Bracket	81–95	60–70

Table 8–2 Exceptions – Metric Fastener Torque Specifications

SERVICE TOOLS

Listed in Table 8–3 are the service tools used in this section.

Tool Number	Tool Name
J 41251	Belt Tension Gauge

Table 8–3 Tools Used to Service the Electrical System

9 POWER TAKE–OFF

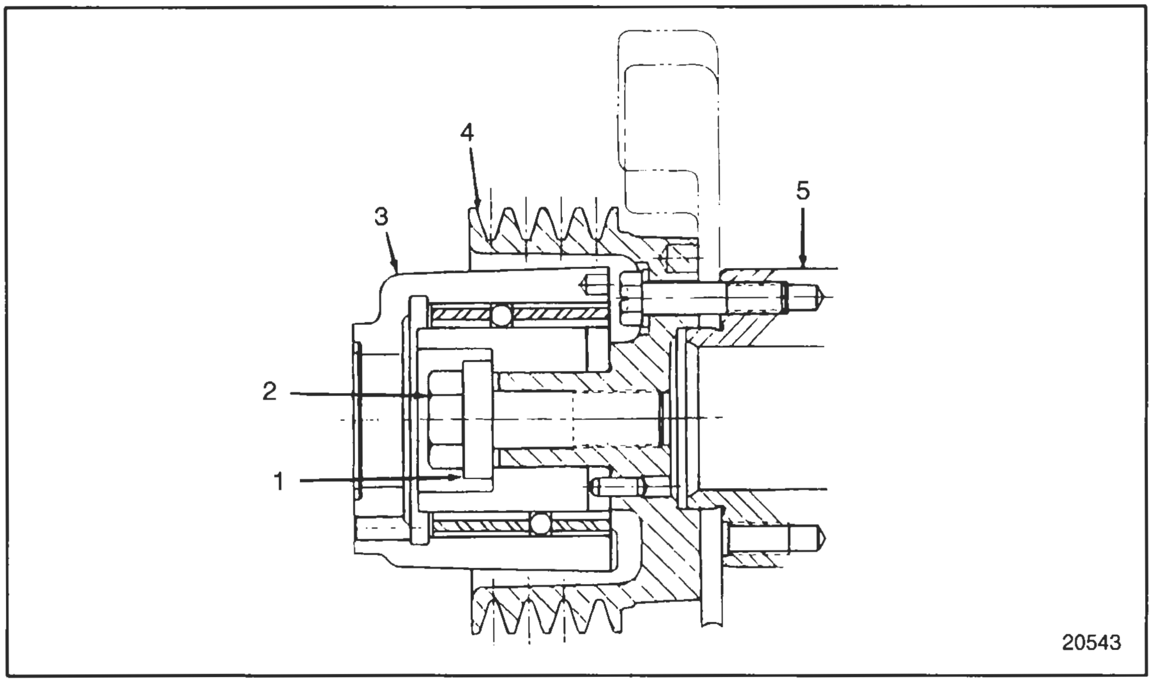
Section **Page**

9.1 REAR MOUNTED POWER TAKE–OFF

There is no rear mounted power take–off (PTO) available for use on the Series 50 engines at this time.

9.2 FRONT MOUNTED POWER TAKE–OFF

Detroit Diesel Corporation (DDC) has front mounted PTO for use on the Series 50 engines. See Figure 9–1.



1. Retainer
2. Bolt
3. Hub Assembly
4. Pulley Assembly
5. Crankshaft

Figure 9–1 Front Mounted Power Take–off Components

This PTO is available in two different models, adaptable to Spicer 1310 and Spicer 1350 drive shafts depending on the torque and horsepower requirements. Maximum torque and horsepower for the two PTO assemblies are listed in Table 9–1.

Power Take–off Models	Engine Speed	Torque	Horsepower
Spicer 1310	1800 r/min	162.7 N·m (120 lb·ft)	30.6 kW (41 hp)
Spicer 1310	2100 r/min	158.7 N·m (117 lb·ft)	29.8 kW (40 hp)
Spicer 1350	1800 r/min	261.7 N·m (193 lb·ft)	57.4 kW (77 hp)
Spicer 1350	2100 r/min	253.6 N·m (187 lb·ft)	56.0 kW (75 hp)

Table 9–1 Torque and Horsepower for the Front Mounted Power Take–off Assemblies

NOTE:
These torque and horsepower values are the maximum available taken at three degrees shaft angle. Any increase in the shaft angle has a direct negative effect on the amount of available torque and horsepower, as well as shaft life.

Also, any new application must have a "Torsional Analysis" performed by the DDC Engineering Department.

The PTO drive shaft must be purchased through Spicer Universal Joint Division, Dana Corporation.

If a PTO adaptor kit is to be installed on an engine that has been in service it will be necessary to remove the standard pulley configuration and replace it with one of the PTO adaptor kits.

Perform the following steps to install the new PTO assembly:

1. Remove the six bolts that retain the standard crankshaft pulley; refer to section 1.13.
2. Install the new PTO pulley, refer to section 9.2.3. Be certain to use the new bolts and washer provided with the PTO adaptor kit.
3. Install the new hub insulator assembly inside the new pulley assembly making certain that the slot on the backside of the hub fits over the dowel in the pulley.
4. Install the new 1 in.–14 x 3.50 in. long bolt and retainer after coating the bolt threads and underside of the bolt head with International Compound. Torque the bolt to 610 N·m (450 lb·ft).

9.2.1 Repair and Replacement of the Front Mounted Power Take–off Assembly

The front mounted power take–off assembly is a nonserviceable component, tag for remanufacture.

9.2.2 Removal of the Front Mounted Power Take–off

Perform the following steps to remove the PTO assembly:

1. Remove the inspection plug in the bottom of the flywheel housing and install the flywheel lock, J 36375. See Figure 9–2.

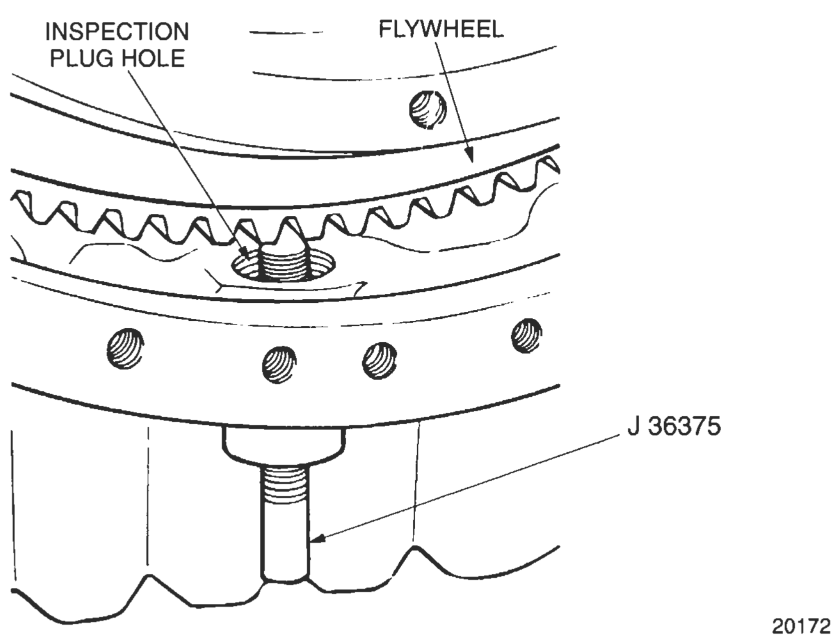


Figure 9–2 Flywheel Lock

2. Thread the center screw of the flywheel lock, J 36375, into the flywheel housing until the tip of the tool rests between two teeth of the flywheel ring gear. Tighten the knurled knob finger tight. See Figure 9–2.

NOTE:
It may be necessary to bar the engine over so that the tool center screw is exactly between two teeth.

3. Remove the PTO hub assembly attaching bolt and retainer.
4. Remove the PTO hub assembly.
5. Remove the crankshaft pulley. Refer to section 1.13.2.

9.2.2.1 Inspection of the Front Mounted Power Take–off

Visually inspect the PTO hub contact surfaces for galling or burrs. To correct surfaces that have damage, smooth these surfaces with emery cloth or a stone.

9.2.3 Installation of the Front Mounted Power Take–off

Install the PTO assembly as follows:

1. If removed, install J 36375 to the inspection plug hole in the bottom of the flywheel housing. See Figure 9–2.
2. Install the crankshaft pulley. Refer to section 1.13.3.
3. Install the PTO hub assembly inside of the crankshaft pulley making sure the slot on the backside of the hub fits over the dowel in the pulley.
4. Install the PTO hub assembly attaching bolt and retainer after coating the bolts threads and underside of the bolt head with International Compound Number 2 or equivalent. Torque the bolt to 610 N·m (450 lb·ft).

9.A ADDITIONAL INFORMATION

Description **Page**

SERVICE TOOLS

Listed in Table 9–2 are the service tools used in this section.

Tool Number	Tool Name
J 36375	Flywheel Lock

Table 9–2 Service Tools

10 SPECIAL EQUIPMENT

10.1 AIR COMPRESSOR

The Series 50 air compressor is flange mounted to the air compressor drive assembly, located on the left side of the engine at the rear of the gear case. See Figure 10-1.

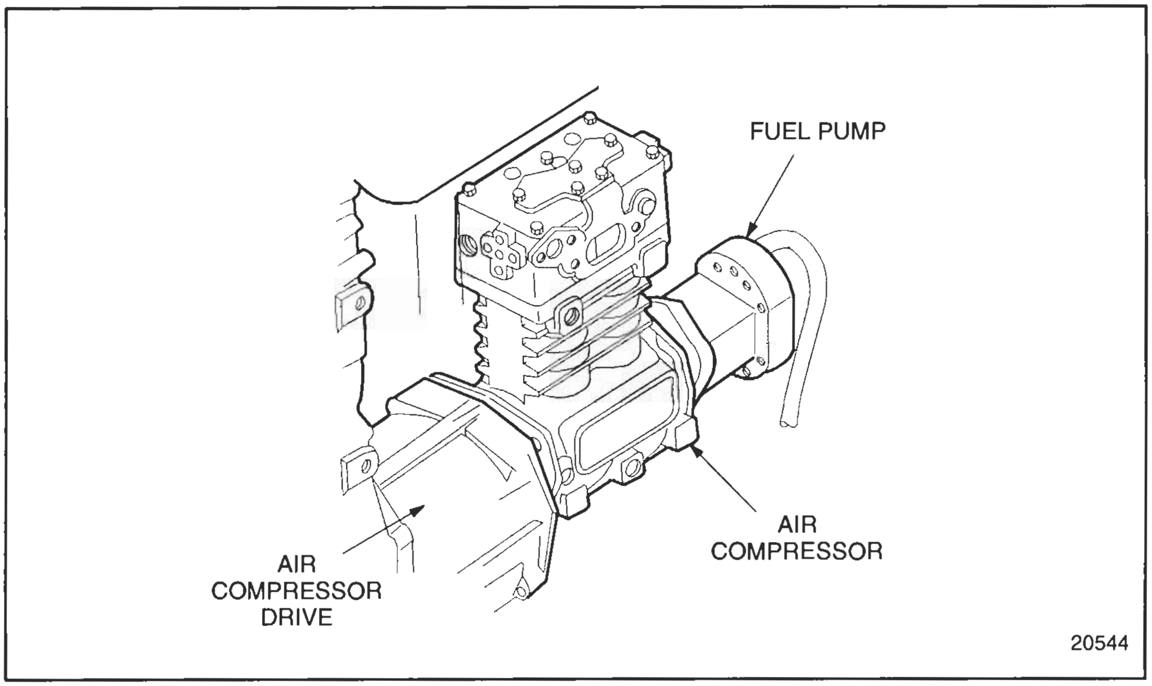


Figure 10–1 Air Compressor Mounting

This air compressor also drives the engine fuel pump which is bolted to the rear end of the compressor. The compressor crankshaft is designed to accept a drive coupling placed between the compressor and fuel pump.

The compressor is driven by the bull gear. The air compressor is water cooled. Engine coolant is fed to the compressor through a flexible hose tapped into the engine block water jacket and connected to the front of the compressor. Coolant returns from the rear of the compressor through a flexible hose to the engine cylinder head. Lubricating oil is supplied to the compressor by a line from the cylinder block oil gallery that connects to the air compressor. Lubricating oil returns to the engine crankcase through the air compressor drive assembly. The Series 50 air compressor is unique compared to the DDC two cycle engines because of its special forged crankshaft, drive hub, and nut.

10.1.1 Replacement of Air Compressor

Detroit Diesel does not service the air compressor. Service of air compressors should be referred to an authorized service center of the original equipment manufacturer.

To replace the air compressor, perform the following procedure. See Figure 10–2.

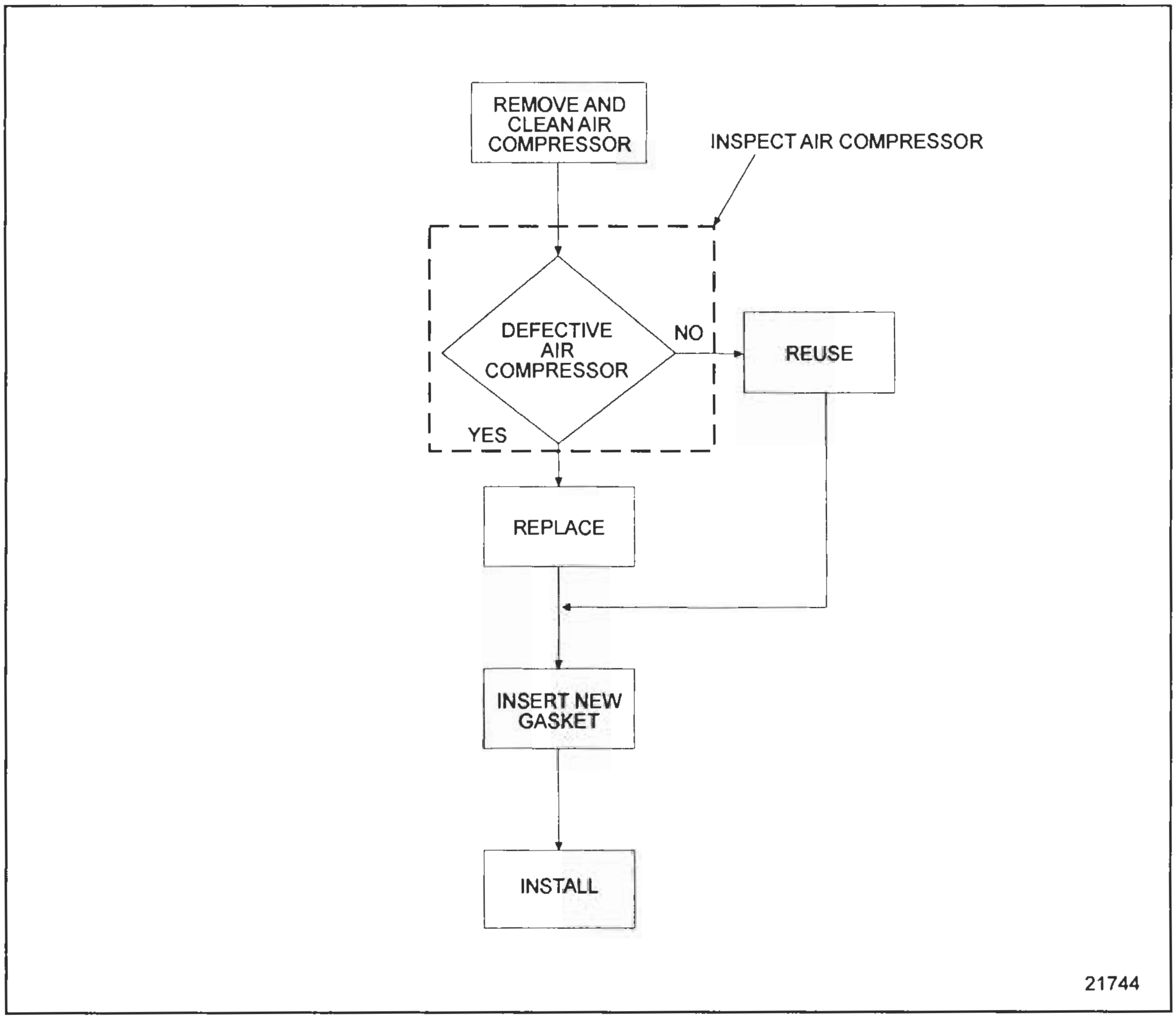


Figure 10–2 Flowchart for Replacement of Air Compressor

10.1.2 Cleaning and Removal of Air Compressor

Precleaning is not necessary.

Remove the air compressor as follow:

1. Disconnect the air lines to and from the compressor.
2. Disconnect the fuel pump lines.
3. Remove the fuel pump and drive coupling. Refer to section 2.5.2.
4. Drain the cooling system. Refer to section 13.5.2.
5. Disconnect and remove the coolant supply and return lines at the air compressor.
6. Disconnect the lubricating oil supply line from the compressor.
7. Remove an unused compressor discharge port plug on the top or side of the compressor head, if necessary for installation of a pressure relief valve.
8. Remove the bolts securing the air compressor support bracket from the cylinder block and air compressor.
9. Remove the support bracket.

NOTE:
Due to the cylinder block and compressor configuration, the upper inside air compressor–to–air compressor drive bolt is difficult to reach with standard tools. Compressor wrench, J 35948, will facilitate removal and installation of this bolt.

10. Remove the bolts that secure the air compressor to the air compressor drive assembly.
11. Slide the air compressor rearward to disengage the hub from the coupling.

10.1.3 Inspection of Air Compressor

Refer to OEM guidelines to determine if the air compressor needs to be repaired or replaced.

10.1.4 Installation of Air Compressor

Install the air compressor as follows:

1. Clean all gasket material from the mating surfaces of the air compressor and air compressor drive.
2. Using a new gasket, install the air compressor to the air compressor drive. Refer to section 10.3.5 for air compressor drive assembly replacement procedure. Mate the internal teeth of the drive hub with the external teeth of the coupling.
3. Install the pressure relief valve into the open discharge port plug. Using a 7/8 in. (No. 14 metric) deep socket, carefully tighten the valve to 23–31 N·m (17–23 lb·ft) torque.
4. Align the bolt holes of the two components and install the air compressor–to–air compressor drive bolts. Tighten the bolts to 101–126 N·m (75–93 lb·ft) torque. Use compressor wrench, J 35948, to tighten the upper–inside bolt.
5. Install the air compressor support bracket to the compressor and cylinder block. Tighten the support bracket–to–air compressor bolts to 18–23 N·m (13–17 lb·ft) torque.
6. Tighten the support bracket–to–cylinder block bolts to 58–73 N·m (43–54 lb·ft) torque.
7. Install the coolant supply and return lines and connect to the air compressor.
8. Install the lubricating oil supply line to the compressor.
9. Install the air lines to and from the compressor.
10. If the unit has a compressor driven fuel pump, install the fuel pump. Refer to section 2.4.6.
11. Refer to section 13.5.4 to fill the cooling system.

10.2 AIR COMPRESSOR DRIVE HUB

The air compressor crankshaft will turn while removing or tightening the drive hub retaining nut unless some provision is made to hold it. One method is to weld a modified drive coupling to a support or base which can be anchored to the mounting flange of the compressor.

A Series 71 or 92 flywheel housing cover that matches the flange of the compressor makes an ideal base for the modified coupling. When positioned, the exterior splines of the coupling mesh with the internal splines of the drive hub and the assembly is secured to the compressor housing. The shaft is then kept from rotating when the nut is loosened or tightened, by the hub and key.

10.2.1 Replacement of Air Compressor Drive Hub

To replace the air compressor drive hub, perform the following procedure. See Figure 10–3.

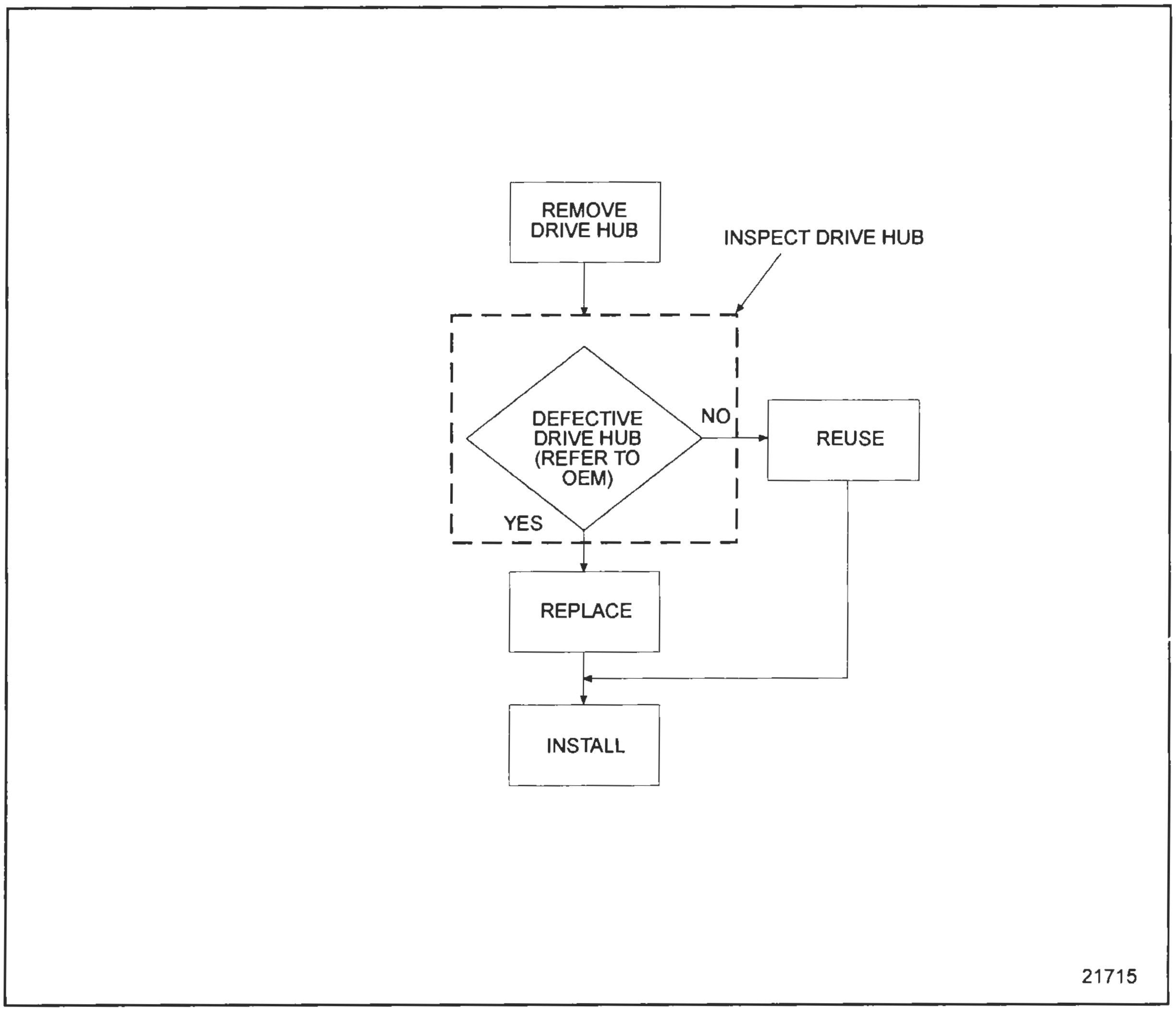


Figure 10–3 Flowchart for Replacement of Air Compressor Drive Hub

10.2.2 Cleaning and Removal of Air Compressor Drive Hub

Precleaning is not necessary.

Refer to section 10.1.2 for removal of the air compressor.

To keep the shaft from rotating, perform the following:

To properly position the cover and coupling with the drive hub, four collars, 19 mm O.D. and 12.7 mm I.D., 19 mm long (3/4 in. O.D. and 1/2 in. I.D., 3/4 in. long), and two pieces of bar stock 19 mm x 19 mm x 102 mm (3/4 in. x 3/4 in. x 4 in.) must be fabricated and welded to the flywheel housing cover at the positions shown in the next illustration. See Figure 10–4.

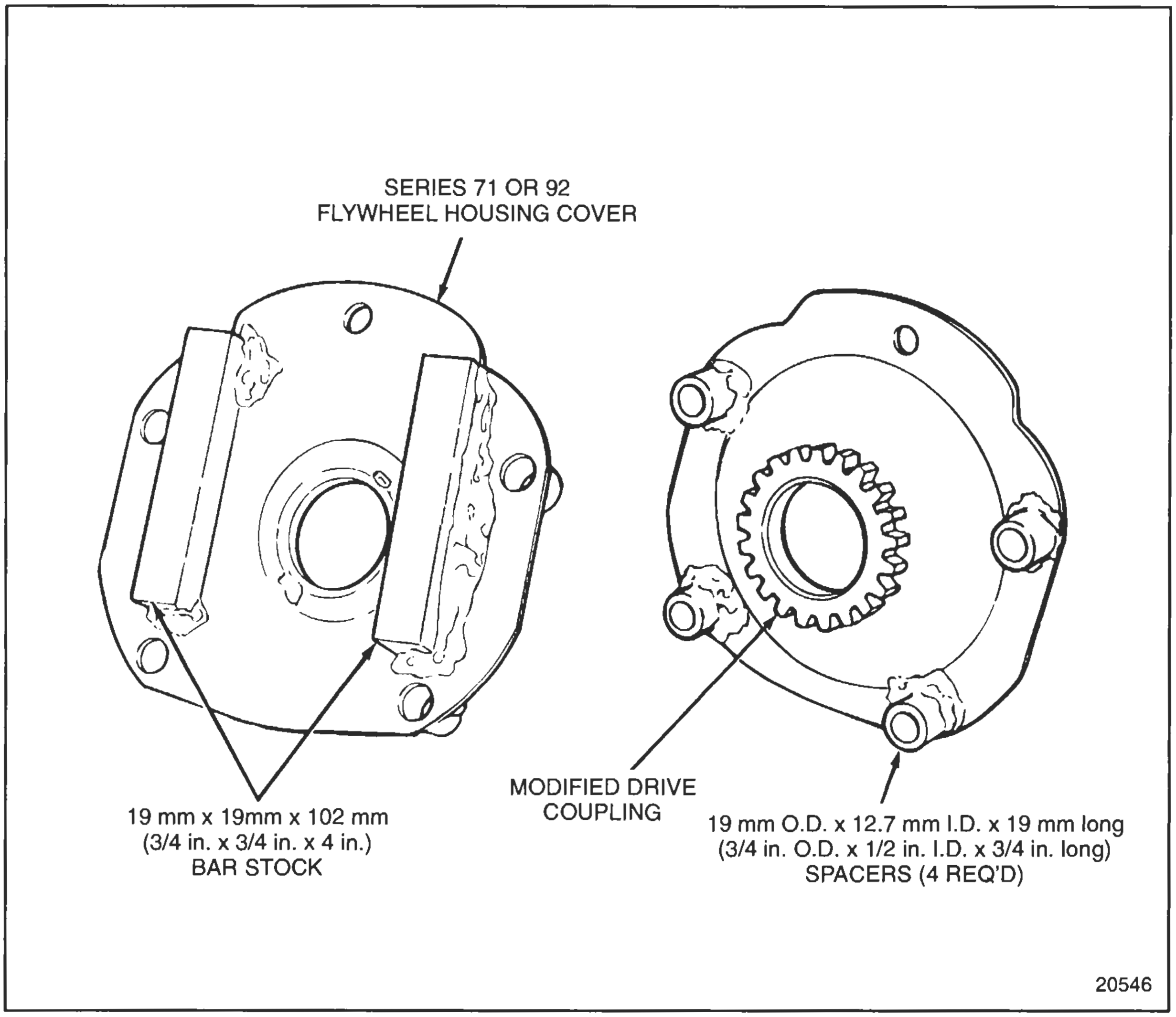


Figure 10–4 Holding Fixture

Position the coupling into the drive hub. Lay the flywheel housing cover over the coupling, center the collars over the compressor housing bolt holes, and tack weld the cover to the coupling.

The diameter of the cover hole must be opened up to the same diameter as the coupling inside diameter to permit access to the drive hub retaining nut. Two bolts will secure the base to the compressor during the operation.

Remove the air compressor drive hub as follows:

1. Install the holding fixture to the flange of the air compressor, engaging the coupling with the internal teeth of the drive hub. Install two bolts to secure the fixture to the compressor. See Figure 10–5.

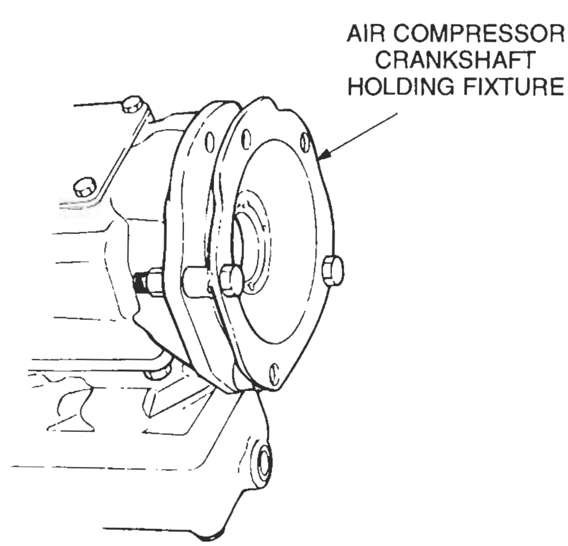


Figure 10–5 Air Compressor Crankshaft Holding Fixture Installation

2. Loosen and remove the drive hub retaining nut.
3. Remove the drive hub from the air compressor by lifting the hub off of the shaft.

10.2.3 Inspection of Air Compressor Drive Hub

Refer to OEM guidelines to determine if the air compressor drive hub needs to be repaired or replaced.

10.2.4 Installation of Air Compressor Drive Hub

Install the air compressor drive hub as follows:

NOTICE:
The drive hub and nut on the Series 50 have a unique configuration. Only the correct part numbers should be used.

1. Install the key to the keyway on the air compressor shaft. Align the keyway in the drive hub with the key in the air compressor crankshaft.
2. Install the hub to the shaft as far as it will go by hand. Do not cock or jam the hub. See Figure 10-6.

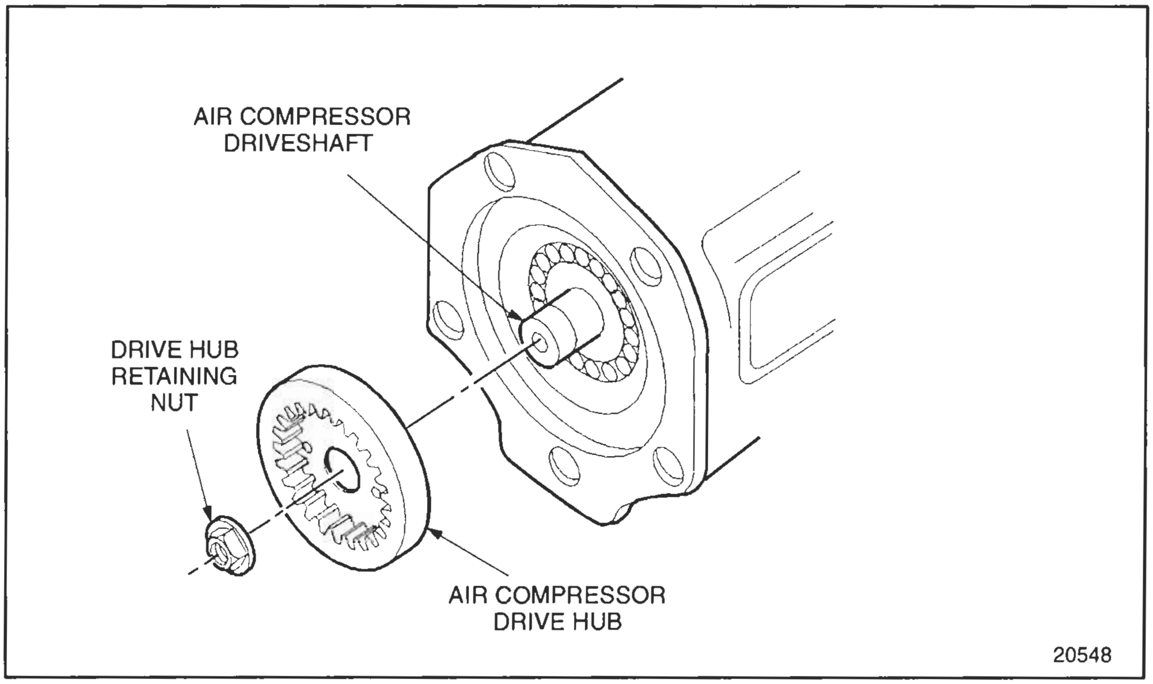


Figure 10–6 Air Compressor Drive Hub Assembly

3. Install the drive holding fixture to the flange of the air compressor, engaging the coupling with the internal teeth of the drive hub. Install two bolts to secure the fixture to the compressor. See Figure 10-5.

4. Tighten the air compressor drive hub retaining nut to 300–345 N·m (220–255 lb·ft) torque. See Figure 10–7.

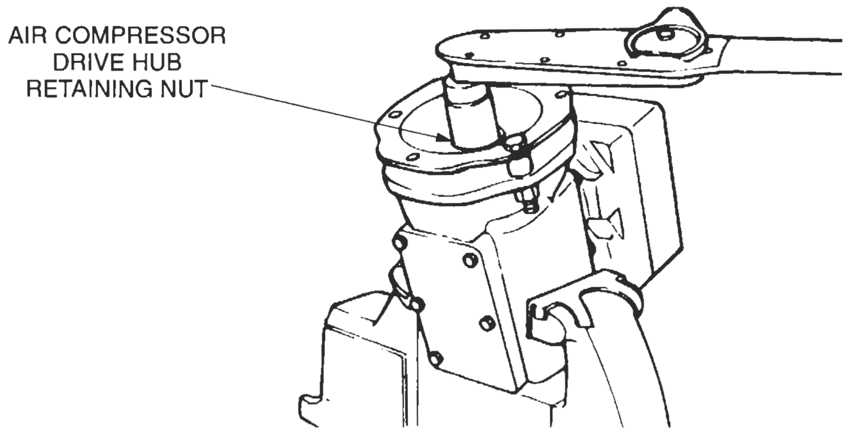
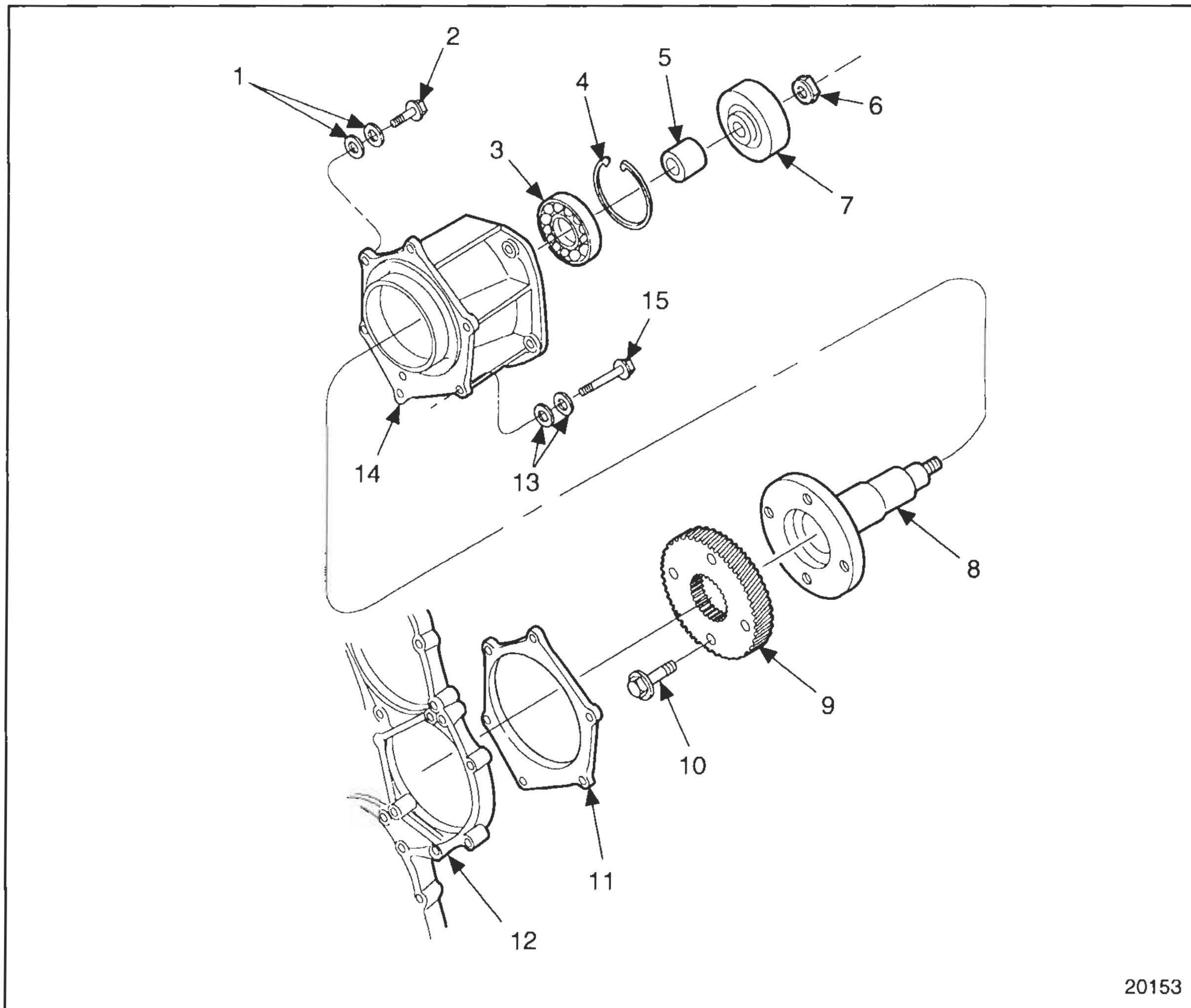


Figure 10–7 Torquing Drive Hub Retaining Nut

5. Loosen the two bolts that retain the holding fixture to the compressor flange, and remove the holding fixture.

10.3 AIR COMPRESSOR DRIVE ASSEMBLY

The air compressor drive assembly mounts to the rear of the gear case on the intake side of the engine. See Figure 10-8.



1. Plain Washers (Shims)
2. Short Bolt, Air Compressor Drive Housing–to–Gear Case (1)
3. Ball Bearing, Air Compressor Drive
4. Snap Ring
5. Spacer
6. Flange Nut, Air Compressor Drive Hub
7. Hub, Air Compressor Drive
8. Shaft, Air Compressor Drive
9. Gear, Air Compressor Drive
10. Bolt, Air Compressor Drive Gear–to–Shaft
11. Gasket, Air Compressor Drive Housing–to–Gear Case
12. Gear Case
13. Plain Washers (Shims)
14. Housing, Air Compressor Drive

Figure 10–8 Air Compressor Drive Detail and Location of Parts

A drive gear meshes with the bull gear and is driven at a ratio of 1.19:1.

The drive gear is bolted to the air compressor drive shaft. A drive hub is installed onto the opposite end of the air compressor drive shaft, and is used to drive the air compressor. On vehicles with power steering, a short splined coupling connects the drive gear to the power steering pump. The coupling is inserted in the splined center of the air compressor drive gear.

Two composition gaskets are used, one to seal the air compressor drive housing to the gear case, and one to seal the air compressor to the drive housing.

10.3.1 Replacement of Air Compressor Drive Assembly

To replace the air compressor drive assembly, perform the following procedure. See Figure 10-9.

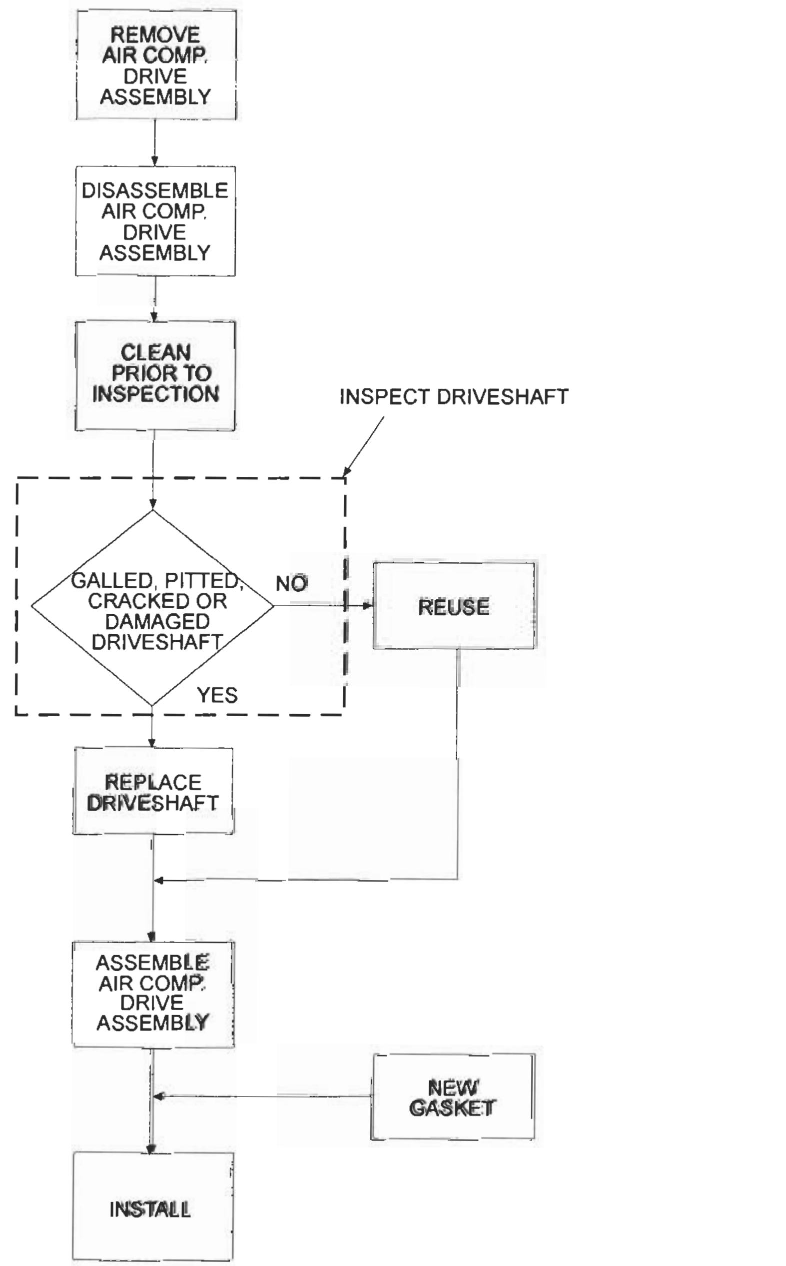


Figure 10–9 Flowchart for Replacement of Air Compressor Drive Assembly

10.3.2 Cleaning and Removal of Air Compressor Drive Assembly

Precleaning is not necessary.

Remove the drive assembly as follows:

1. If equipped, remove the air compressor. Refer to section 10.1.2.
2. If equipped with power steering, loosen and remove the five bolts securing the power steering pump and cover assembly to the gear case cover.
3. Remove the pump and cover assembly.
4. Remove the power steering drive coupling from the air compressor drive gear.
5. Disconnect the oil supply lines from the "T" fitting, if applicable, at the top of the air compressor drive housing.
6. Remove the six bolts that secure the air compressor drive assembly to the gear case.
7. Remove the assembly by pulling it straight out of the gear case.

NOTE:
The short bolt in the two o'clock position is for installation reference.

10.3.3 Disassembly of Air Compressor Drive Assembly

Disassemble the air compressor drive assembly as follows:

1. Secure the holding fixture, See Figure 10–4, in a suitable vise with the drive coupling facing up. See Figure 10–10.

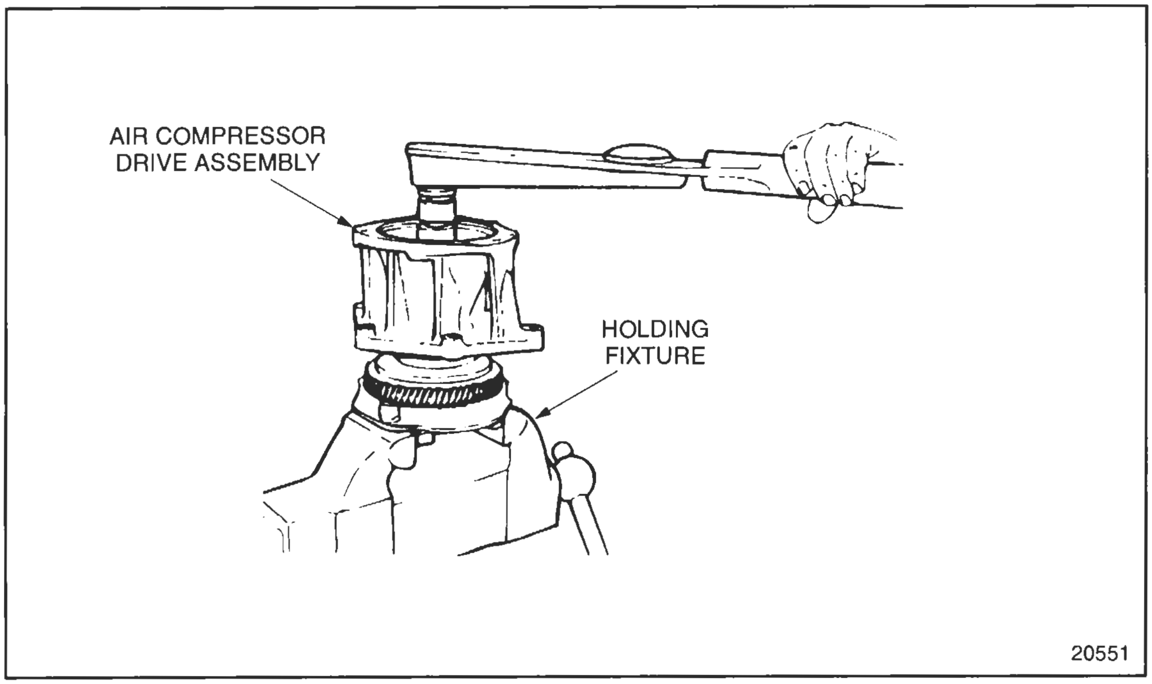


Figure 10–10 Air Compressor Drive Hub Disassembly

2. Position the air compressor drive assembly onto the holding fixture, engaging the internal teeth of the drive gear with the coupling on the holding fixture.
3. Loosen and remove the flanged nut retaining the drive hub to the drive shaft.
4. Remove the drive hub from the air compressor drive assembly.
5. Remove the spacer from the drive shaft (current air compressor drive only).
6. Remove the drive assembly from the holding fixture and place on bench.
7. Remove the four bolts that secure the drive gear to the drive shaft flange and remove gear.

8. Use the air compressor and fan drive service tool set, J 36310–A, for disassembly. See Figure 10–11.

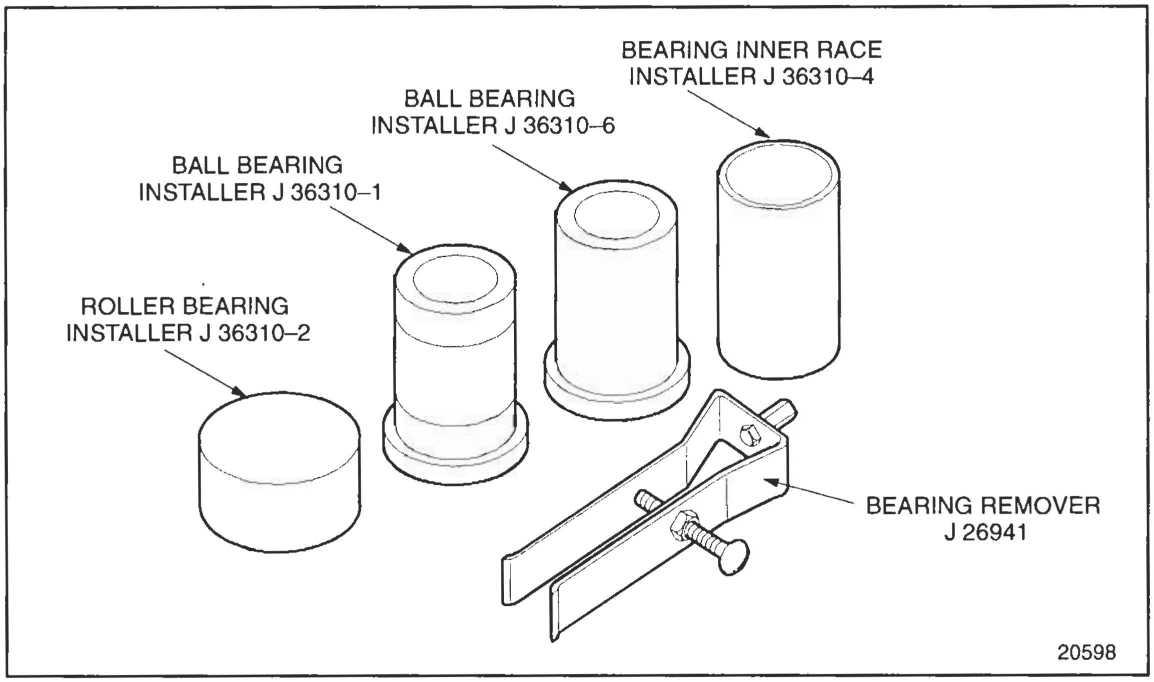


Figure 10–11 Air Compressor and Fan Drive Service Kit Set

9. Support the air compressor drive housing on press plates with the drive hub side facing up.
10. Press the air compressor driveshaft out of the drive housing.

NOTE:
Whenever the driveshaft is removed from the housing, the ball bearing assembly must be replaced.

11. Remove the large snap ring retaining the ball bearing in the air compressor drive hub housing using snap ring pliers. See Figure 10–12.

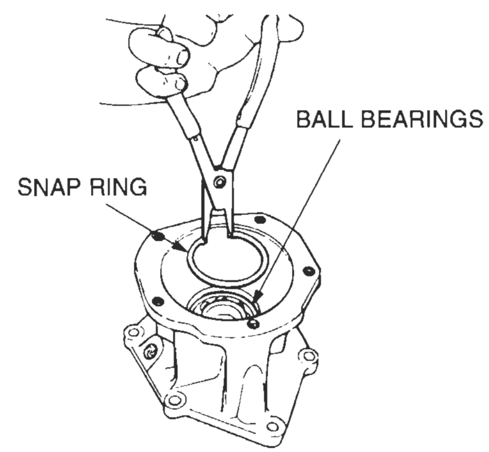


Figure 10–12 Roller Bearing Snap Ring Removal

12. On current design air compressor drive only, turn the air compressor drive housing over and support it on the press bed.
13. Using the narrow end of bearing installer, J 36310–6, against the bearing, press the bearing from the housing.
14. Discard the bearing.

NOTE:
The following steps apply only to the former design air compressor drive.

15. Using the snap ring pliers, turn the drive assembly over, and remove the large snap ring retaining the roller bearing in the air compressor drive housing. See Figure 10–13.

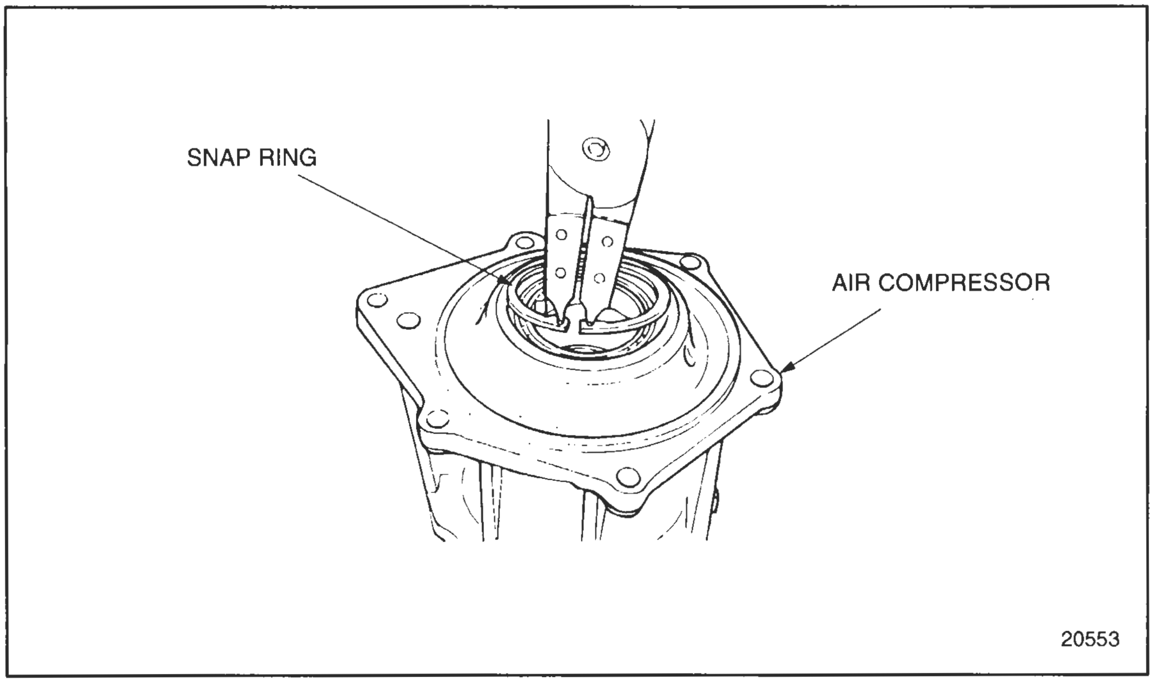


Figure 10–13 Ball Bearing Snap Ring Removal

NOTE:
Whenever the bearings are removed from the housing, the bearing assemblies must be replaced.

16. Install the lip of the bearing remover, J 26941, under the bearing. See Figure 10–14.

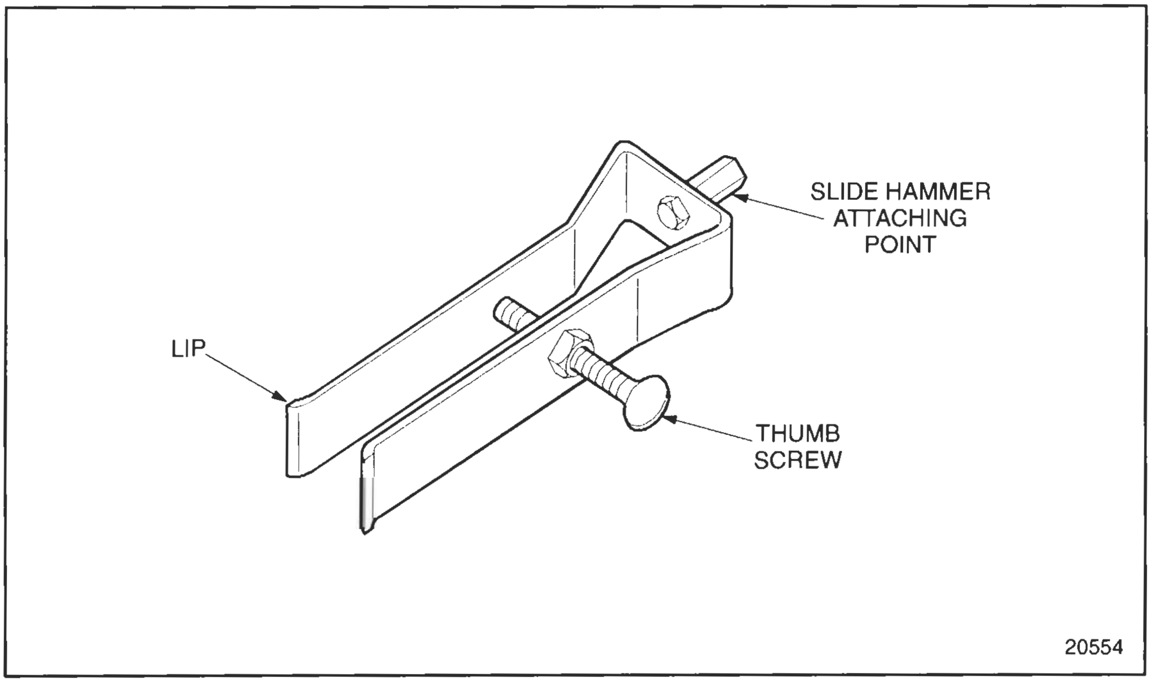


Figure 10–14 Bearing Remover

17. Tighten the thumb screw on the bearing remover until it is snug against the bearing.
18. Install a suitable slide hammer to the top of the bearing remover. Remove the bearing.
19. Repeat this procedure to remove the other bearing from the housing.

20. Using snap ring pliers, remove the small snap ring retaining the roller bearing inner race on the air compressor driveshaft. See Figure 10-15.

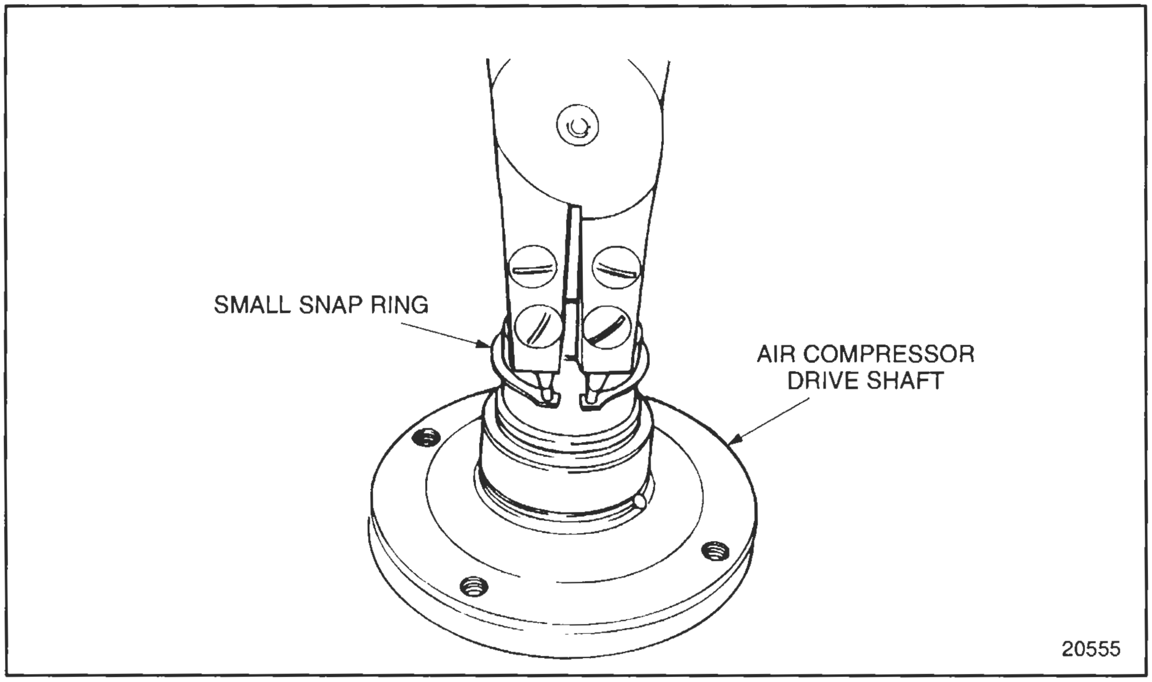


Figure 10–15 Roller Bearing Inner Race Snap Ring Removal

21. Using a punch and hammer, work through the two access holes to drive the roller bearing inner race from the air compressor driveshaft. See Figure 10-16.

NOTE:
Whenever the roller bearing inner race is removed from the shaft, the roller bearing assembly must be replaced.

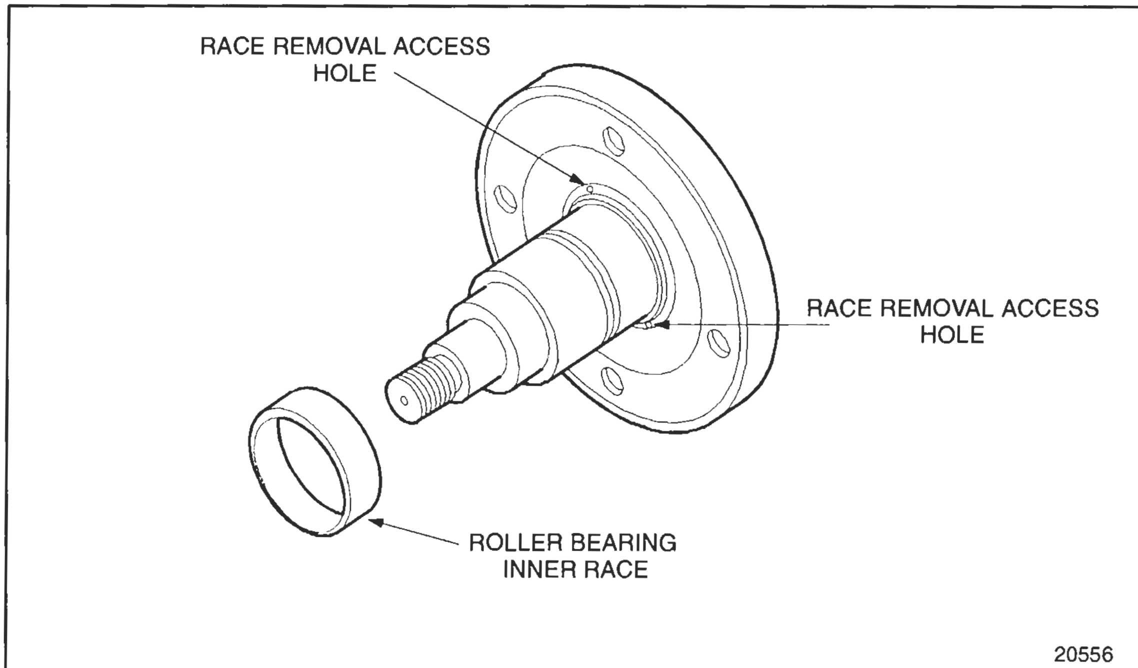


Figure 10–16 Bearing Inner Race Removal

Clean the air compressor drive assembly prior to inspection as follows:

1. Clean all of the parts with clean fuel oil.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

2. Dry with compressed air.

10.3.3.1 Inspection of the Air Compressor Drive Assembly

Inspect the air compressor drive assembly as follows:

1. Inspect the driveshaft for damage.
   [a] Check driveshaft for galling, pitting, cracks, or other damage.
   [b] If driveshaft is damaged, replace with new part.

10.3.4 Assembly of Air Compressor Drive Assembly

Assemble the air compressor drive assembly as follows:

1. Turn the housing over.

NOTE:
The bearing identification numbers must face the installer when installing the bearing.

2. Install the ball bearing in the air compressor drive housing using a press and the large end of the ball bearing installer, J 36310–1, for the former design or, J 36310–6, for the current design.
3. Press on the outer race of the bearing only. See Figure 10–17.

NOTE:
Be sure the bearing is fully seated against the shoulder in the housing for the snap ring to be installed.

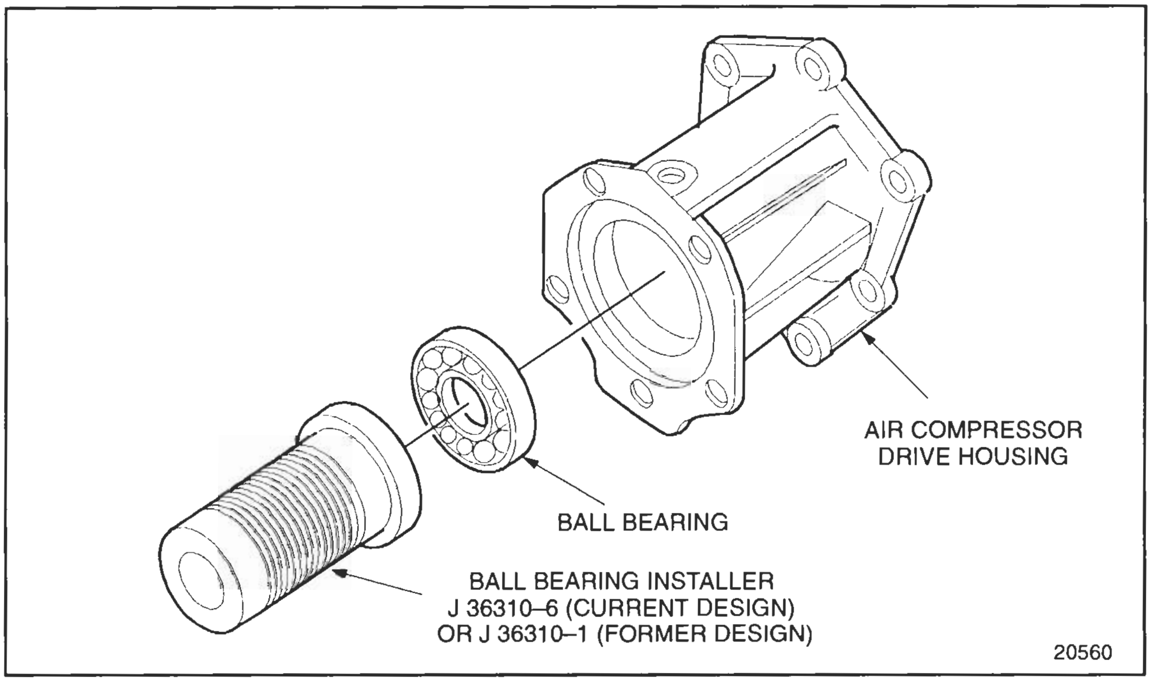


Figure 10–17 Ball Bearing Installation

NOTE:
There is a plastic sleeve in the current design ball bearing which must not be removed when installing the bearing. The sleeve will be pushed out when the drive shaft is installed.

4. Install the snap ring retaining the ball bearing in the housing using snap ring pliers. See Figure 10–18.

NOTE:
Be sure the snap ring is fully seated in its groove in the housing.

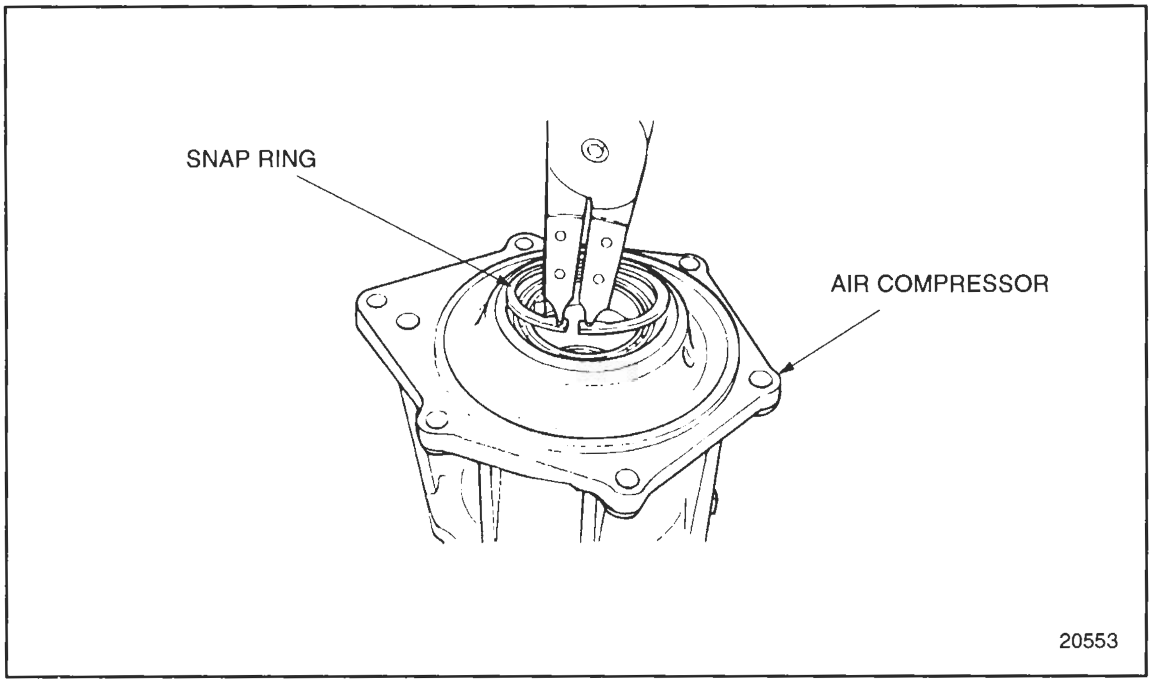


Figure 10–18 Snap Ring Installation

5. Place wide end of ball bearing installer, J 36310-6, on press bed.
6. Place the air compressor drive housing on the bearing installer, making sure that the installer is centered on the bearing inner race.
7. Position the drive shaft in the bearing inner race.
8. Press the drive shaft into the bearing and housing assembly until the shaft shoulder is seated against the bearing inner race.
9. Remove the air compressor drive assembly from the tool.
10. Remove the plastic sleeve from inside of the tool.
11. Discard plastic sleeve.

12. Install the air compressor drive gear to the shaft. See Figure 10–19.

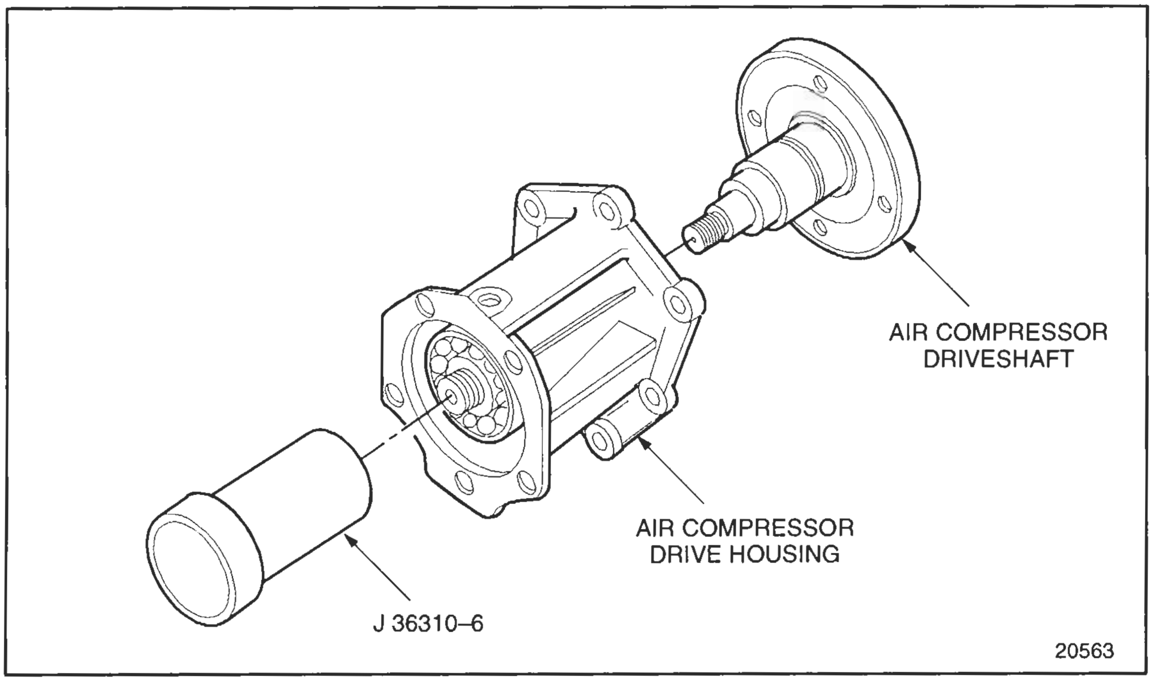


Figure 10–19 Air Compressor Drive Gear Installation

13. Install the four drive gear-to-drive shaft bolts and tighten to 58–73 N·m (43–54 lb·ft) torque.
14. Secure the holding fixture, See Figure 10–4, in a suitable vise with the drive coupling positioned up.
15. Position the air compressor drive assembly on the holding fixture, engaging the internal teeth of the drive gear with the coupling on the fixture.
16. Lubricate the ball bearing with clean engine oil.
17. Place the spacer on the drive shaft seating it against bearing inner race.

18. Place the air compressor drive hub on the drive shaft. See Figure 10–20.

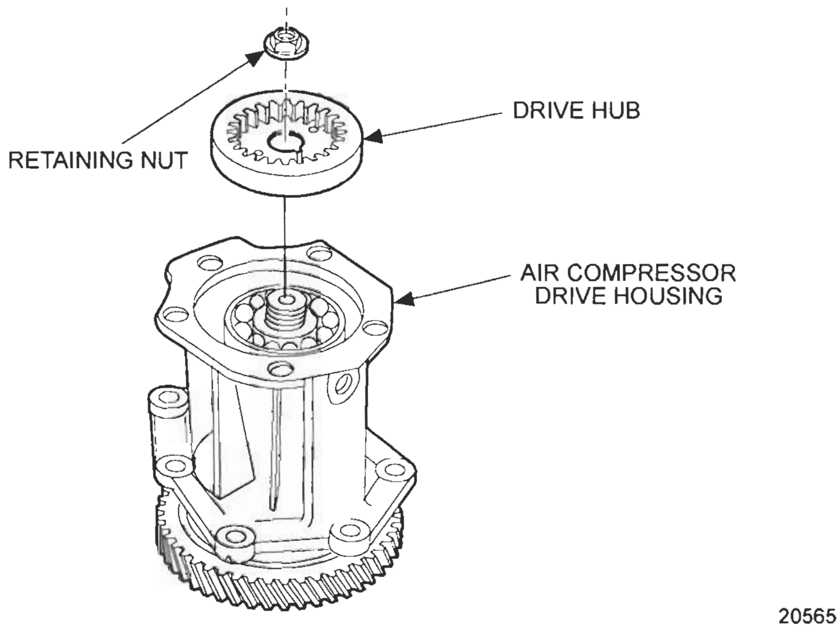


Figure 10–20 Drive Hub Installation

19. Install the flanged nut retaining the drive hub to the drive shaft. Tighten the nut to 300–345 N·m (220–255 lb·ft) torque.
20. Remove the drive assembly from the holding fixture and position it on a suitable flat surface with the drive gear facing up.

21. Assemble a dial indicator and magnetic base so that the indicator stem rests on the face of the drive gear just inboard of the drive gear teeth. See Figure 10–21.

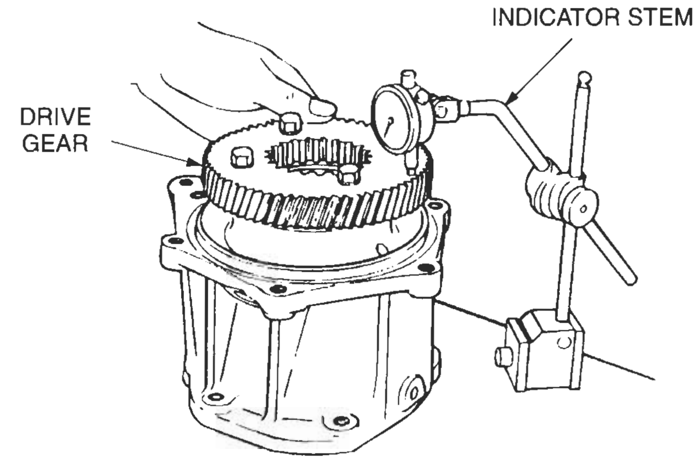


Figure 10–21 Measuring Air Compressor Drive Gear TIR

22. Zero the dial indicator.

23. Rotate the drive gear two full revolutions. As the gear is rotated, the dial indicator may register both to the left and right of zero. The total amount the indicator needle moves to the left and right of zero, added together, gives the total indicated runout (TIR). Maximum allowable TIR is 0.08 mm (.003 in.).

10.3.5 Installation of Air Compressor Drive Assembly

Install the air compressor drive assembly as follows:

1. Install the air compressor drive assembly to its original position in the gear case, using a new gasket between the housing and gear case.
2. Install the bolts that secure the air compressor drive assembly to the gear case, and tighten them to 58–73 N·m (43–54 lb·ft) torque.

NOTE:
The shorter bolt is installed in the two o'clock position.

3. Measure the bull gear-to-air compressor drive gear lash. Refer to section 1.21.2.1.
4. Install the access cover. Use a new gasket between the access cover and the gear case cover, and torque the 5 bolts to 30–38 N·m (22–28 lb·ft) in a star-shaped tightening pattern.
5. If the engine is equipped with a power steering pump, install the proper steering drive coupling and power steering pump and cover assembly to the gear case cover. Install a new gasket between the cover and the gear case cover, and torque the 5 bolts to 30–38 N·m (22–28 lb·ft) in a star-shaped tightening pattern.
6. Connect the oil supply line at the "T" fitting, if applicable, at the top of the air compressor drive housing.
7. Install the air compressor. Refer to section 10.1.4.
8. Install any other components that were removed for this procedure.

10.A ADDITIONAL INFORMATION

SPECIFICATIONS

Specifications are listed in the General Information section at the beginning of the manual. Exceptions are listed below:

Exceptions to Standard Fastener Torque Specifications

Exceptions to Standard Fastener Torque Specifications supporting the Series 50 Engine are listed in Table 10–1.

Fastener	Torque, N·m	Torque, lb·in.
Pressure relief valve–to–discharge port plug	23–31	17–23
Bolts, air compressor–to–air compressor drive bolts	101–126	75–93
Bolts, support bracket–to–air compressor	18–23	13–17
Bolts, support bracket–to–cylinder block	58–73	43–54

Table 10–1 Exceptions – Metric Fastener Torque Specifications

SERVICE TOOLS

Listed in Table 10–2 are the service tools used in this section.

TOOL NO.	TOOL NAME
J 35948	Air Compressor Wrench
J 36310–A	Air Compressor Drive/Fan Hub Service Set
J 36310–1	Ball Bearing Installer (Former Design) of Service Set
J 36310–6	Ball Bearing Installer (Current Design) of Service Set
J 26941	Roller Bearing Remover

Table 10–2 Service Tools

11 OPERATION AND VERIFICATION

11.1 PREPARATION FOR A FIRST TIME START

Before starting an engine for the first time, carefully read and follow the instructions in this section. Also, refer to section 13 of this manual.

NOTICE:
Attempting to run the engine before studying these instructions may result in serious damage to the engine.

NOTICE:
When preparing to start a new or overhauled engine or an engine that has been in storage, perform all of the operations listed below. Before a routine start (at each shift), see Daily Operations in the Preventive Maintenance Chart. Refer to section 13.2. Failure to perform required prestart operations may result in engine damage.

11.1.1 Cooling System

Install all of the drain cocks and plugs in the cooling system as instructed below:

1. Open the cooling system vents.
2. Remove the filler cap and fill the cooling system with a coolant specified. Refer to section 5.3. The coolant level should be within two inches (50 mm) of the filler neck to allow for fluid expansion.
3. Close the vents, if used, after filling the cooling system.

11.1.2 Lubrication System

The lubricating oil film on the rotating parts and bearings of a new or overhauled engine, or one which has been in storage, may be insufficient for proper lubrication when the engine is started for the first time.

It is recommended that the engine lubricating system be charged with a pressure prelubricator, set to supply a minimum of 172 kPa (25 lb/in.^{2}) oil pressure, to ensure an immediate flow of oil to all bearings at the initial engine start-up. The oil supply line should be attached to the engine so that oil under pressure is supplied to the main oil gallery.

With the oil pan dry, use the prelubricator to prime the engine with sufficient oil to reach all bearing surfaces. Use lubricating oil as specified. Refer to section 5.2. Then, remove the dipstick, wipe it with a clean cloth, insert and remove it again to check the oil level in the oil pan. Add sufficient oil, if necessary, to bring it to the *full* mark on the dipstick. Do not overfill.

If a pressure prelubricator is not available, fill the crankcase to the proper level with lubricating oil. Refer to section 13.5.1. Then, prelubricate the upper engine parts by removing the valve rocker cover and pouring lubricating oil, of the same grade and viscosity as used in the crankcase, over the rocker arms, rocker arm shafts, camshaft lobes and camshaft follower rollers.

11.1.3 Turbocharger

When a turbocharger is replaced, or if the engine has been in storage, the turbocharger must be prelubricated by pouring oil into the oil supply inlet before the engine is started. Rotate the shaft to coat the bearings with oil.

NOTICE:
The free floating bearings in the turbocharger center housing require positive lubrication. This is provided by the above procedure before the turbocharger reaches its maximum operating speed which is produced by high engine speeds. Starting any turbocharged engine and accelerating to any speed above idle before engine oil supply and pressure has reached the free floating bearings can cause severe damage to the shaft and bearings of the turbocharger.

Start and run the engine at idle until oil supply pressure has reached all of the turbocharger moving parts. A good indicator that all the moving parts are getting lubrication is when the oil pressure gage registers 138 kPa (20 lb/in.^{2}) pressure at idle speed.

11.1.4 Air Cleaner

Refer to OEM instructions for the air cleaner, and service accordingly.

11.1.5 Transmission

Check the oil level and, if necessary, fill the transmission case or torque converter to the proper level with the lubricant specified by the manufacturer.

11.1.6 Fuel System

Fill the fuel tank with the fuel specified. Refer to section 5.1.

If the unit is equipped with a fuel valve, it must be opened. To ensure prompt starting, the fuel system between the pump and fuel return line must be full of fuel.

If the engine has been out of service for a considerable length of time, prime the fuel system between the fuel pump and the fuel return manifold. Before priming the fuel system, remove and fill both fuel filters with clean fuel oil and reinstall them.

NOTE:
The engine fuel system is filled with fuel before leaving the factory. If the fuel is still in the system when preparing to start the engine, priming should be unnecessary.

11.1.7 Drive Belts

Adjust all drive belts as recommended. Refer to section 13.5.7.

11.1.8 Storage Battery

Check the battery. The top should be clean and dry, the terminals tight and protected with a coat of silicone spray or petroleum jelly and the electrolyte must be at the proper level.

A hydrometer reading (corrected for the temperature of the electrolyte) should be 1.265 or higher. If necessary, charge the battery.

11.1.9 Clutch

Disengage the clutch, if the unit is so equipped.

11.2 STARTING

Before starting the engine for the first time, perform the operations listed under "Preparation For Starting Engine First Time."

Before a routine start, see "Daily Maintenance–All Applications"
Refer to section 13.2.

Start an engine equipped with an electric starting motor as follows:

1. Turn the ignition switch to the "ON" position. The yellow check engine and red stop engine lights should both light up. After 6–10 seconds both lights should go out. If both lights fail to go out, refer to section 15.2 in 6SE494 *Series 50 Troubleshooting Manual* for instructions on monitoring the DDEC system.

NOTICE:
To prevent serious damage to the cranking motor, if the engine does not start, do not press the starting switch again while the cranking motor is spinning.

2. If the check engine and stop engine lights both go out, press the starting motor switch firmly. If the engine fails to start within 15 seconds, release the starting switch and allow the starting motor to cool for 15 seconds before trying again. If the engine fails to start after four attempts, an inspection should be made to determine the cause.

11.3 RUNNING

The following sections cover normal operations.

11.3.1 Oil Pressure

Observe the oil pressure gage immediately after starting the engine. If there is no pressure indicated within 10 to 15 seconds, or the stop engine light (red) comes on, stop the engine and check the lubricating oil system. Refer to the troubleshooting manual for the appropriate troubleshooting charts.

11.3.2 Warm–up

Make sure area is well–ventilated before starting the engine.

CAUTION:

The exhaust products of an internal combustion engine are toxic and may cause injury or death if inhaled. All engine installations, especially those within closed shelter or buildings should be equipped and maintained with an exhaust discharge pipe so that exhaust gases are delivered into the outside air. A closed building or shelter must be adequately vented. A means of providing fresh air into a closed building or shelter is necessary.

Run the engine at idle with no–load for approximately five minutes, allowing it to warm–up before applying a load. The engine will idle at a higher speed if the oil is cold when started.

As the engine reaches operating temperature, the engine's electronic control system will lower the idle speed if not equipped with an automatic transmission.

If the unit is operating in a closed room, start the room ventilating fan or open the windows and doors, as weather conditions permit, so ample air is available for the engine.

11.3.2.1 Inspection

While the engine is running at operating temperature, check for coolant, fuel or lubricating oil leaks. Tighten the line connections where necessary to stop leaks.

11.3.3 Engine Temperature

Refer to section 11.5 for normal operating temperature.

11.3.4 Crankcase

If the engine crankcase was refilled, stop the engine after normal operating temperature has been reached, allow the oil to drain (approximately 20 minutes) back into the crankcase and check the oil level. Add oil, if necessary, to bring it to the proper level on the dipstick.

Use only the lubricating oil specified. Refer to section 5.2.

11.3.5 Cooling System

Several types of cooling systems are used by vehicle manufacturers. Refer to vehicle owner's manual for specific instructions.

CAUTION:

Use extreme care when removing a radiator cap in a pressurized system. The sudden release of pressure from a heated cooling system can result in loss of coolant and possible personal injury (scalding) from the hot liquid.

Remove the radiator cap slowly and check the engine coolant level. The coolant level should be within two inches of the top of the opening. If necessary, add properly inhibited coolant.

11.3.6 Turbocharger

Make a visual inspection of the turbocharger for leaks and excessive vibration. Stop the engine immediately if there is an unusual noise in the turbocharger.

11.3.7 Avoid Unnecessary Engine Idling

During long engine idling periods, the engine coolant temperature will fall below the normal operating range. The incomplete combustion of fuel in a cold engine will cause crankcase dilution, formation of lacquer or gummy deposits on the valves, pistons and rings and rapid accumulation of sludge in the engine.

NOTE:
When prolonged engine idling is necessary, maintain at least 800 r/min.

11.4 STOPPING

The following should be performed for NORMAL stopping:

1. Release the load and decrease the "engine speed" in the NEUTRAL position.
2. Allow the engine to run at idle with no-load for a few minutes, then turn the key switch to the "OFF" position.

The following should be performed after a NORMAL stop:

1. Fill fuel tank. A full tank will minimize condensation.
2. Check coolant level. Add coolant, if necessary, to bring it to the proper level.
3. Check the oil level in the crankcase. Add oil, if necessary, to bring it to the proper level on the dipstick.
4. Check and, if necessary, add sufficient fluid to bring it to the proper level. Follow manufacturer's recommendations for proper levels.
5. Make a visual check for external leaks in the fuel, lubricating and cooling systems.

11.4.1 Emergency Stopping

To stop the engine, turn the key to the "OFF" position.

11.5 OPERATING CONDITIONS

The operating limits for the Series 50 engine are listed in Table 11-1 and listed in Table 11-2. Any variations from the conditions as listed may indicate an abnormal situation in need of correction. Be sure that the readings represent true values and the instruments are accurate before attempting to make corrections to the engine. This data represents rated conditions. Actual data may be influenced by environmental conditions.

Parameter Limits	Operating Limits at 2100 r/min	Operating Limits at 1800 r/min
Lubricating oil pressure (at rated speed)–kPa (lb/in.^{2})	345 (50)	345 (50)
Minimum for safe operation (idle) kPa (lb/in.^{2})	83 (12)	83 (12)
In gallery oil temperature, maximum – °C (°F)	110 (230)	110 (230)
Oil flow–liters/minute (gallons/minute)	109 (29)	91 (24)
Oil pan capacity: High–liters (quarts)	21 (22)	21 (22)
Oil pan capacity: Low–liters (quarts)	18 (19)	18 (19)
Total engine oil capacity (with filters)–liters (quarts)	28 (26)	28 (26)

Table 11–1 Series 50 Lubrication System Parameters

Air, Fuel and Cooling System Parameter Description	Operating Limit at 2100 r/min	Operating Limit at 1800 r/min
Air System		
Air Inlet restriction full load, maximum – kPa (in. H_2O):		
Dirty air cleaner	5.0 (20)	5.0 (20)
Clean air cleaner	3.0 (12)	3.0 (12)
Crankcase pressure full load, maximum–kPa (in. H_2O)	0.75 (3)	0.75 (3)
Exhaust back pressure, maximum–kPa (in. Hg):		
Full load	10.1 (3.0)	10.1 (3.0)
Maximum allowable temperature rise (ambient air to engine inlet) – °C (°F)	16.7 (30)	16.7 (30)
Maximum allowable charge air cooler pressure drop – kPa (in. Hg)	10.1 (3.0)	10.1 (3.0)
Fuel System		
Fuel pressure at secondary filter outlet – kPa (lb/in.^{2})		
Normal with 2.03 mm (0.080 in.) restriction	577 (75)	577 (75)
Minimum	345 (50)	345 (50)
Fuel spill minimum at no–load – L/min (gal/min):		
Normal with 2.03 mm (0.080 in.) restriction	4.9 (1.3)	4.1 (1.0)
Fuel pump suction at pump inlet, maximum – kPa (in. Hg):		
Clean system	20 (6)	20 (6)
Dirty system	41 (12)	41 (12)
Cooling System		
Coolant temperature normal – °C (°F)	88 (190)	88 (190)
Coolant inlet restriction, maximum – kPa (in. Hg)	0.0 (0.0)	0.0 (0.0)
Coolant flow at full load speed–L/min (gal/min)	341 (90)	276 (73)
Engine coolant capacity – liters (quarts)	17 (16)	17 (16)
Minimum pressure cap – kPa (lb/in.^{2}):	62 (9.0)	62 (9.0)
Maximum top tank temperature – °C (°F)	99 (210)	99 (210)
Minimum top tank temperature – °C (°F)	71 (160)	71 (160)
Thermostats:		
Start to open – °C (°F)	86 (186)	86 (186)
Fully open – °C (°F)	97 (207)	97 (207)

Table 11–2 Series 50 Air System, Fuel System, and Cooling System Parameters

11.6 ENGINE RUN–IN INSTRUCTIONS

Following a complete overhaul or any major repair that uses replacement piston rings, pistons, or bearings, for example, the engine should be run–in on a dynamometer prior to release for service.

The dynamometer is a device for applying specific loads to an engine to determine if the engine will perform to published specifications and to permit a physical inspection for leaks of any kind. It is an excellent method for detecting improper tune–up, misfiring injectors, low compression and other malfunctions, and may save an engine from damage at a later date.

The operating temperature within the engine affects the operating clearances between the various moving parts of the engine and determines to a degree how the parts will wear.

NOTICE:
Thermostats are required to control the coolant flow and to help maintain a constant engine temperature. Therefore, be sure that they are in place and fully operative or the engine may overheat during the run–in. Furthermore, a deaeration line must be installed in the uppermost portion of the engine to prevent any overheat problems during run–in.

The rate of water circulation through the engine on a dynamometer should be sufficient to avoid having the engine outlet water temperature more than 5.6°C (10°F) higher than the water inlet temperature. A 5.6°C (10°F) rise across an engine is recommended; however, an 8.3°C (15°F) temperature rise maximum is permitted.

11.6.1 The Basic Engine

A basic engine includes only those components actually necessary to run the engine. The addition of any engine driven accessories will result in a brake horsepower figure less than the values shown in the Engine Run–In Check. The fan and battery–charging alternator typify accessories not considered on the basic engine.

Since the DDEC system requires a source of electrical power to operate the Electronic Unit Injectors, all DDEC equipment should be connected and operating properly. In addition, a fully charged battery must be connected to the system. Refer to OEM guidelines.

In situations where other than basic engine equipment is used during the test, a proper record of this fact should be made on the Engine Test Report. The effects of additional equipment on engine performance should then be considered when evaluating test results.

11.6.2 Dynamometer Test and Run–in Procedure

The function of the dynamometer is to absorb and measure the engine output. Its basic components are a frame, provisions for engine mounting, the absorption unit, a heat exchanger, and a torque loading and measuring device.

For accurate dynamometer readings during a Series 50 engine run–in, the chassis dynamometer room *must* be properly ventilated. See Figure 11–1.

CALIFORNIA
Proposition 65 Warning

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

Figure 11–1 California Proposition 65 Warning

CAUTION:

Exhaust products of an internal combustion engine may cause illness, injury, or death if inhaled in certain quantities. Always start and operate an engine in a well–ventilated area. If inside a building or other enclosed area, engine exhaust should be vented into the outside air. Do not modify or tamper with the exhaust system.

The engine is connected through a universal coupling to the absorption unit. The load on the engine may be varied from zero to maximum by decreasing or increasing the resistance in the unit. The amount of power absorbed in a water brake type dynamometer, as an example, is governed by the volume of fluid within the working system. The fluid offers resistance to a rotating motion. By controlling the volume of water in the absorption unit, the load may be increased or decreased as required.

The power absorbed is generally measured in torque (lb·ft) on a suitable scale. This value for a given engine speed will show the brake horsepower developed in the engine by the following formula, see Figure 11–2.

$$BHP = \frac{T_1 \times RPM}{5250} \qquad kW = \frac{T_2 \times RPM}{9429}$$

WHERE;

BHP	=	BRAKE HORSEPOWER, hp
kW	=	POWER, kW
T_1	=	TORQUE, ft·lb
T_2	=	TORQUE, N·m
RPM	=	ENGINE SPEED, r/min
5250	=	DYNAMOMETER CONSTANT
9429	=	DYNAMOMETER CONSTANT

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Figure 11–2 Formulas for Power Developed in the Engine

Some dynamometers indicate direct brake horsepower readings. Therefore, the use of the formula is not required when using these units.

During the actual operation, all data taken should be recorded immediately on an Engine Test Report, see Figure 11–3.

SERIES 50 ENGINE TEST REPORT

Date: ____________ Unit Number: ____________
Repair Order Number: ____________ Model Number: ____________
PROM I.D.: ____________ Max. N/L RPM: ____________
Rated F/L RPM: ____________
Idle RPM: ____________

A. PRESTART

1. PRIME LUBE OIL SYSTEM	2. PRIME FUEL OIL SYSTEM	3. FILL COOLING SYSTEM

B. START-UP AND IDLE FOR 30 SECONDS

START__________ STOP __________ OIL PRESSURE __________ WATER TEMPERATURE __________

C. WARM-UP — 5 MINUTES **START** __________ **STOP** __________

RPM MAX. SPEED	LOAD 50%	OIL PRESSURE	WATER TEMPERATURE
1. LUBE OIL LEAKS	2. FUEL OIL LEAKS	3. COOLANT LEAKS	4. LOOSE BOLTS

D. RUN-IN — 5 MINUTES **START** __________ **STOP** __________

RPM MAX. SPEED	LOAD 75%	OIL PRESSURE	WATER TEMPERATURE

E. FINAL RUN-IN — 20 MINUTES **START** __________ **STOP** __________

RPM MAX. SPEED	LOAD 100%	CRANKCASE PRESSURE AT F/L	EXHAUST BACK PRESSURE AT F/L
LUBE OIL PRESS. AT F/L	LUBE OIL TEMP. AT F/L	FUEL OIL TEMP. AT F/L	FUEL OIL PRESSURE AT F/L
WATER TEMP. AT F/L	TURBO BOOST PRESS. AT F/L	LUBE OIL PRESSURE AT IDLE	IDLE RPM

REMARKS:

OK __________ Reject __________ Dynamometer Operator __________ Date __________

24336

Figure 11–3 Series 50 Engine Test Report Form

11.6.2.1 Instrumentation

Certain instrumentation is necessary so that data required to complete the Engine Test Report may be obtained. The following list contains the minimum amount of instruments and the proper location of the fittings on the engine so that the readings represent a true evaluation of engine conditions.

- ❑ Oil pressure gage installed in one of the engine main oil galleries (DDEC data can also be used)
- ❑ Water temperature gage installed in the thermostat housing or water outlet manifold
- ❑ Adaptor for connecting a pressure gage or water manometer to the crankcase
- ❑ Fuel pressure gage at the rear of the cylinder head

In some cases, gages reading in pounds per square inch are used for determining pressures while standard characteristics are given in inches of mercury or inches of water. It is extremely important that the scale of such a gage be of low range and finely divided if accuracy is desired. This is especially true of a gage reading in lb/in.^{2}, the reading of which is to be converted to inches of water. The following conversion factors may be helpful.

Gage reading = (lb/in.^{2}) x 27.7 inches of water

Gage reading = (lb/in.^{2}) x 2.04 inches of mercury

NOTICE:
Before starting the run–in or starting the engine for any reason following an overhaul, it is of extreme importance to observe the instructions; see "Preparation for a First Time Start:" refer to section 11.1. Failure to follow instructions could result in engine damage.

11.6.2.2 Run–in Procedure

Use the following procedure for preparation of engine run–in.
See Figure 11–3 part A.

1. Fill and prime the lubrication system as outlined under Lubrication System, "Preparation for a First Time Start." Refer to section 11.1.
2. Prime the fuel system as outlined under Fuel System, "Preparation for a First Time Start." Refer to section 11.1.
3. Make a preliminary valve clearance adjustment before the engine is started. Refer to section 12.2.
4. Make a preliminary injector timing check before starting the engine. Refer to section 12.2.
5. Be sure that the turbocharger has been prelubricated by adding oil to the turbocharger oil inlet or by pressurizing the lubrication system.
6. Check to be sure all test stand water valves, fuel valves, etc. are open.
7. Inspect the exhaust system, checking that it is properly connected to the engine.

Use the following procedures for engine run–in:

1. Start the engine with minimum dynamometer resistance.

NOTICE:
All Series 50 engines should be operated at idle for at least one minute after starting to assure oil supply and pressure to the turbocharger bearings. Inadequate lubrication will result in bearing damage.

2. Set the engine throttle at idle speed; idle for 30 seconds. Record oil pressure and water temperature values on the engine Test Report; see Figure 11–3, Part B. Check all connections to be sure there are no leaks.

3. The Engine Test Report sample, see Figure 11–3, establishes the sequence of events and specifications for the test and run-in. Also, refer to section 11.5 for *"Operating Conditions"*, which presents the engine operating characteristics. These characteristics will be a guide for tracing faulty operation or lack of power. After checking the engine performance at idle speed and being certain the engine and dynamometer are operating properly, increase the engine speed to half speed and apply the load indicated on the Warm–Up – 5 minutes; see Figure 11–3, Part C. Complete leak information.
4. Run the engine at this speed and load for 5 minutes to allow sufficient time for the coolant temperature to reach the normal operating range. Record length start and stop times, speed, brake horsepower, coolant temperature and lubricating oil pressure on the Engine Test Report; see Figure 11–3, Part D.
5. Run the engine at each speed and rating for the length of time indicated in the Engine Run–In Schedule. During this time, engine performance will improve as new parts begin to seat in.
6. Inspect the engine for fuel oil, lubricating oil and water leaks.
7. Upon completion of the run–in and inspection, remove the load from the dynamometer and reduce the engine speed gradually to idle and then stop the engine.
8. Record all data requested; see Figure 11–3, Part E.

NOTE:
Allow the engine to idle at least 3 minutes in order for the turbocharger to cool and reduce speed before shutdown.

After all of the tests have been made and the Engine Test Report is completed, see Figure 11–3, Part D., the engine is ready for final test, see Figure 11–3, Part E. This portion of the test and run–in procedure will assure the engine owner that his engine has been rebuilt to deliver factory rated performance at the same maximum speed and load which will be experienced in the installation.

If the engine has been shut down for one hour or longer, it will be necessary to have a warm up period of five minutes at the same speed and load used for warm–up. If piston rings or bearings have been replaced as a result of problems during the warm–up, the entire run–in must be repeated as though the test and run–in procedure were started anew.

All readings observed during the final run–in should fall within the range specified in the "Operating Conditions", refer to section 11.5, and should be taken at full load unless otherwise specified. Following is a brief discussion of each condition to be observed.

- ☐ The engine water temperature should be taken during the last portion of the run–in at full load. It should be recorded and should be within the specified range.
- ☐ The lubricating oil pressure should be recorded in kPa or $lb/in.^2$ after being taken at engine speeds indicated in the "Operating Conditions," refer to section 11.5.
- ☐ Check the crankcase pressure, refer to section 58.3 in the *Series 50 Troubleshooting Manual*, while the engine is operating at maximum run–in speed. Attach a manometer to the oil dipstick opening; refer to section 44.1 in the *Series 50 Troubleshooting Manual*, calibrated to read inches of water.

The following steps are necessary to complete the final Engine Repair Schedule.

1. Determine the maximum rated brake horsepower and the full–load speed to be used during the final run–in.
2. Apply this load to the dynamometer.
3. The engine should be run at this speed and load for five minutes.

NOTE:
While making the final run–in, the engine should develop the maximum rated brake horsepower indicated for the speed at which it is operating. If this brake horsepower is not developed, the cause should be determined and corrections made.

4. All information, see Figure 11–3, Part E, should be recorded.
5. After the prescribed time for the final run–in has elapsed, remove the load from the dynamometer and reduce the engine speed gradually to idle speed and then stop the engine.
6. A final inspection must be made. This inspection will provide final assurance that the engine is in proper working order. During this inspection, the engine is also made ready for any brief delay in delivery or installation which may occur. This is accomplished by rust proofing the fuel system, refer to section 13.5.2, and adding a rust inhibitor to the cooling system, refer to section 13.5.4.
7. Change the lubricating oil filters.

12 ENGINE TUNE–UP

12.1 ENGINE TUNE–UP PROCEDURES

The Series 50 engine is equipped with Detroit Diesel Electronic Control (DDEC). Since DDEC replaces any mechanical governing devices, and the fuel injectors are electronically controlled, it is unnecessary to perform engine speed adjustments.

CAUTION:

To prevent possible injury, do not perform engine tune–up procedures or engine repair without first disconnecting the engine cranking motor and/or batteries.

CAUTION:

The use of a turbocharger compressor inlet shield does not preclude any other safety practices contained in this manual.

NOTICE:

To prevent possible damage, do not perform engine tune–up procedures or engine repair without first disconnecting the engine cranking motor and/or batteries.

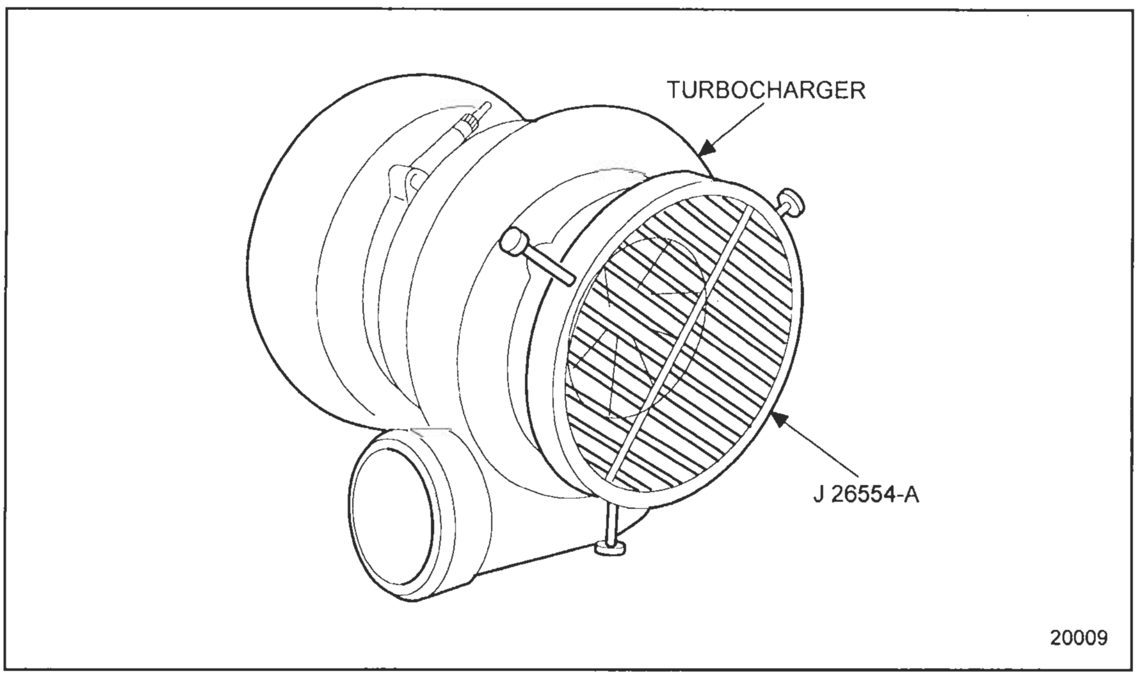


Figure 12–1 Turbocharger Compressor Inlet Shield

The turbocharger compressor inlet shield, J 26554–A, must be used anytime the engine is operated with the air inlet piping removed. See Figure 12–1.

The shield helps prevent foreign objects from entering and damaging the turbocharger and will prevent the mechanic from accidentally touching the impeller.

The tune-up procedure for the Series 50 consists of intake and exhaust valve clearance adjustments, fuel injector height adjustments, and Jake Brake® lash adjustments. These adjustments should be made with the engine cold. Refer to section 12.2.

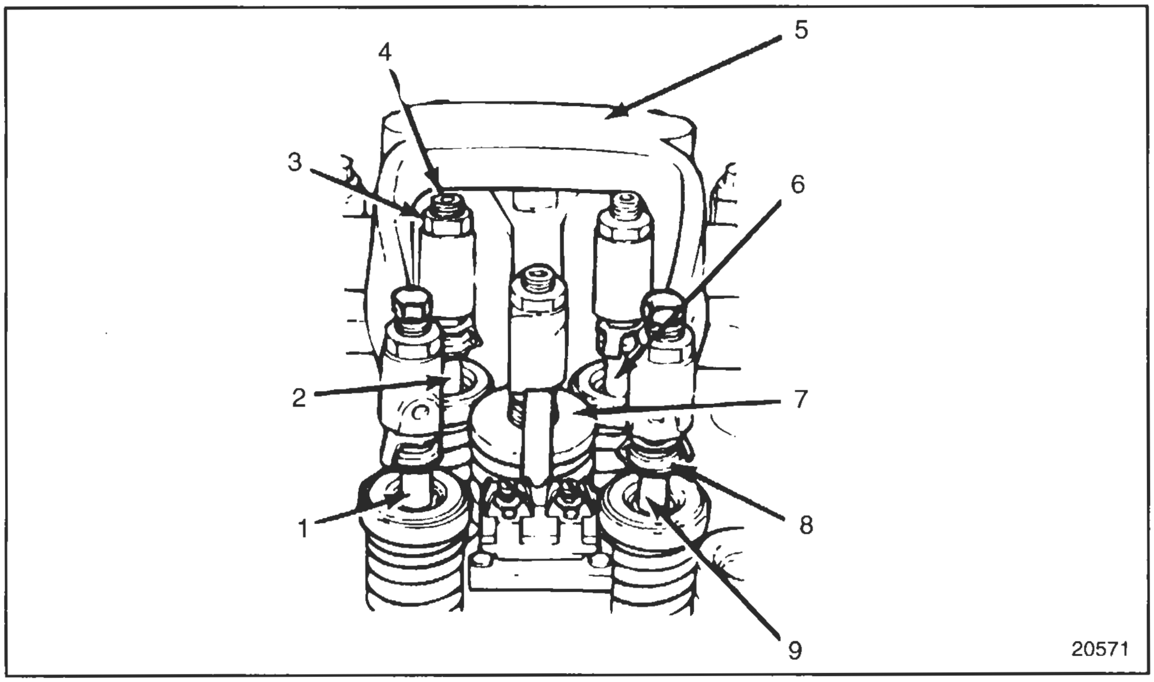
12.2 VALVE LASH, INJECTOR HEIGHT (TIMING) AND JAKE BRAKE ® LASH ADJUSTMENTS

Accurate adjustment of clearance between valve buttons, intake and exhaust valves is important if maximum performance and economy are to be obtained.

Likewise, injector height should be properly maintained.

Intake valve clearance and injector height are adjusted by means of an adjusting set screw and locknut located at the valve (or injector) end of the rocker arm; see Figure 12–2.

NOTE:
On engines equipped with a Jake Brake ®, measure valve lash and injector height before removing any brake housings. Only remove the brake housings necessary to provide access for adjustment.



1. Exhaust Valve
2. Intake Valve
3. Locknut
4. Adjusting Set Screw
5. Exhaust Rocker Arm Assembly
6. Intake Valve
7. Fuel Injector Follower
8. Valve Button
9. Exhaust Valve

Figure 12–2 Valve and Fuel Injector Rocker Arm Assembly Components

NOTICE:
Be sure the height gage seats on the machined surface with the tip in the pilot hole. Foreign material in the pilot hole or on the machined surface may prevent accurate setting of the injector height.

The fuel injector height is adjusted using the injector height gage, J 39697, on DDEC III and injector height gage, J 35637–A, on DDEC II. On engines equipped with a Jake Brake®, move the handle on the injector height gage to the alternate position, 90° to the shank. A height gage pilot hole is provided in the injector body on the machined surface contacted by the injector clamp near the solenoid. See Figure 12–3.

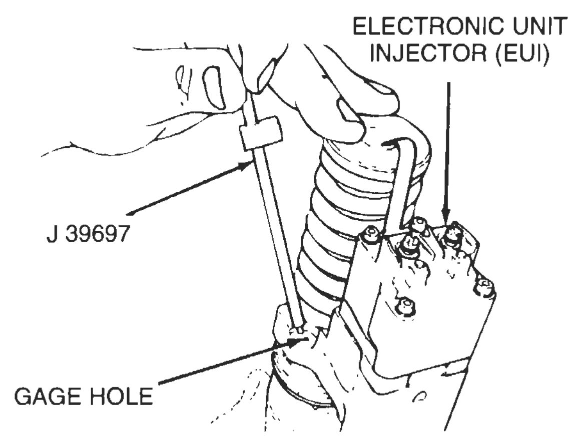
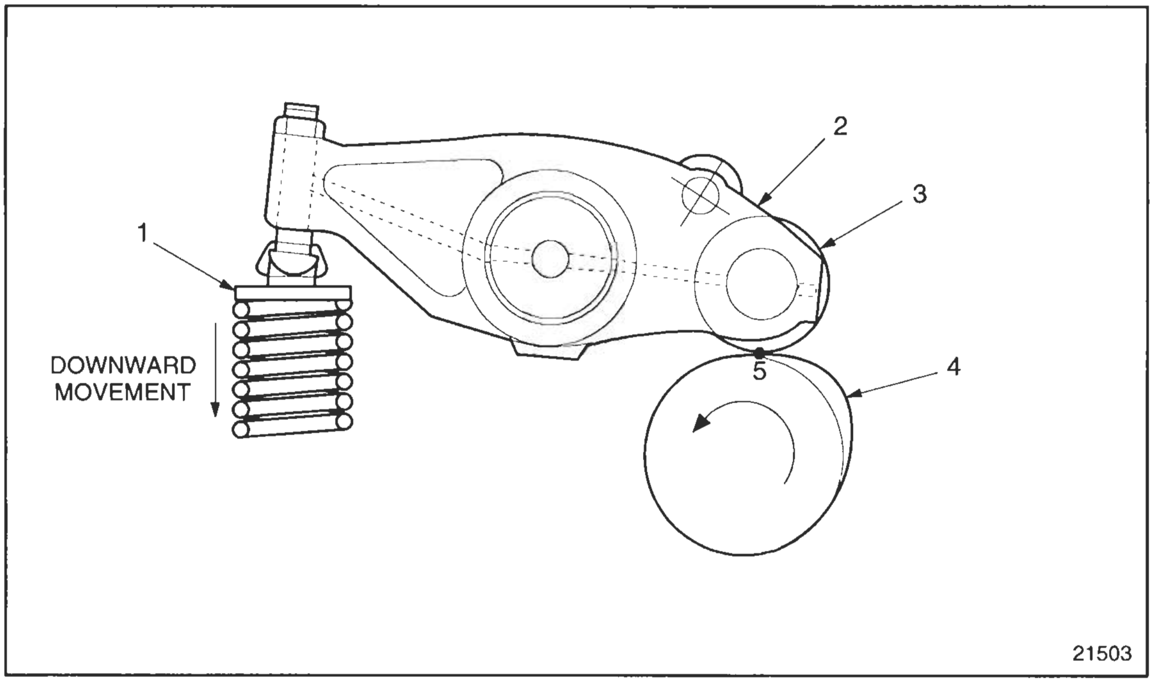


Figure 12–3 Timing Gage

To determine if improper valve clearance, injector height or both are causing the cylinder to misfire, perform the following preliminary step 1. through step 3. and repeat step 4. through step 10. for each cylinder to determine if worn or damaged lobes or rollers are causing the engine to misfire:

1. Disconnect starting power for engine.
2. Remove the engine valve rocker cover. Refer to section 1.6.2.
3. Insert a 3/4 in. drive breaker bar or ratchet into the square hole in the center of the crankshaft pulley.

4. Bar the engine over. Stop engine rotation when any one of the injector followers has just begun its downward stroke; see Figure 12–4.



1. Injector Follower
2. Injector Rocker Arm Assembly
3. Injector Roller
4. Injector Cam Lobe
5. Point on the Camshaft Lobe that First Produces Downward Motion of the Injector Follower

Figure 12–4 Injector Followers Downward Stroke

5. Using the Timing Circle Chart, see Figure 12–5, locate the cylinder requiring clearance. The timing circle can be started with any cylinder and assure that the circle is completed to adjust all valves and injectors.

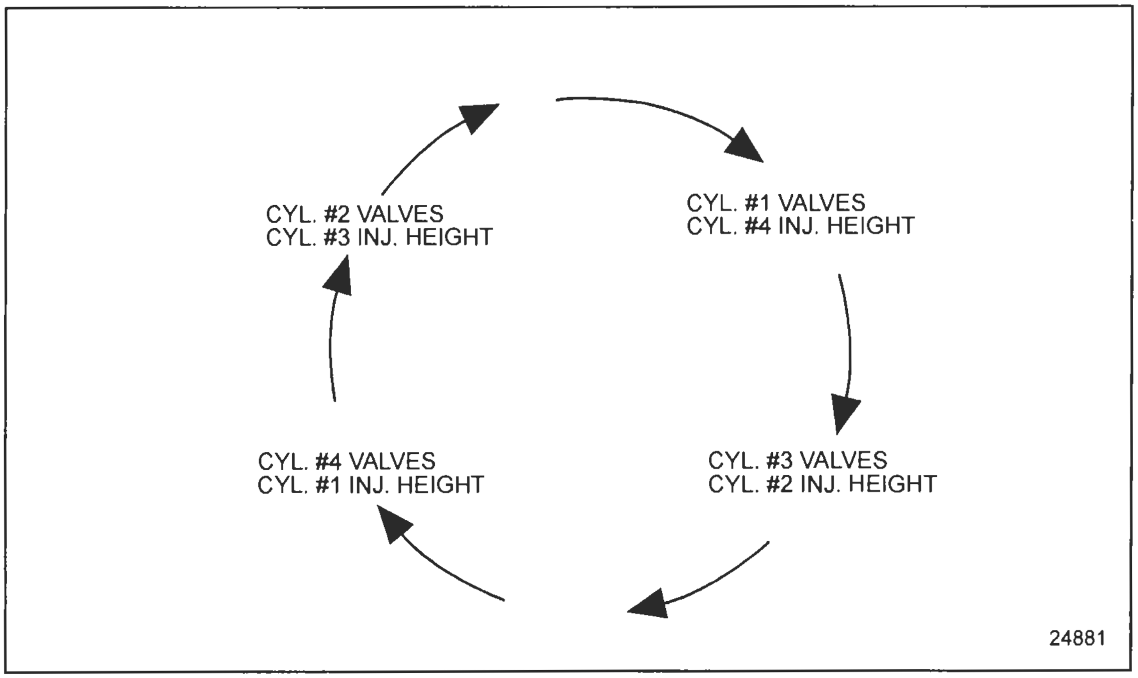
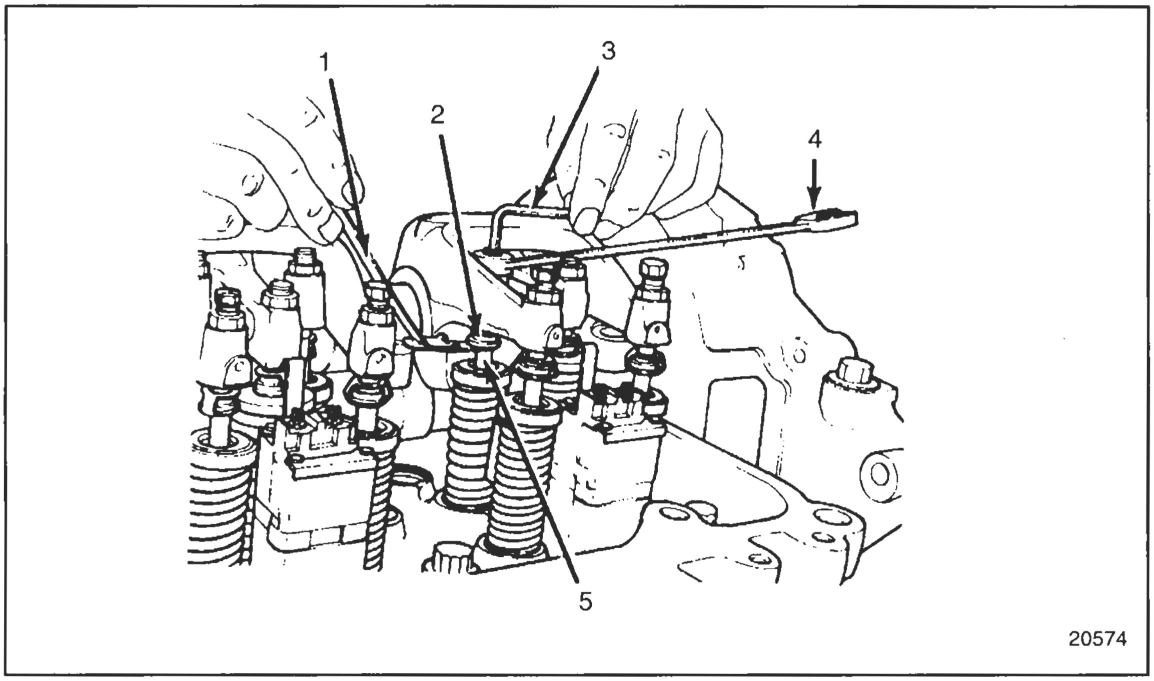


Figure 12–5 Timing Circle Chart

NOTICE:
Never set the valves and injector of the same cylinder at the same time. Doing this will result in engine damage.

6. To adjust the intake valves, insert a 0.203 mm (.008 in.) feeler gage between the tip of the valve stem and the valve button at the end of the rocker arm. See Figure 12–6.
7. Loosen the locknut, and turn the adjusting set screw until the feeler gage produces an even smooth pull between the valve stem and valve button.



1. Feeler Gage
2. Valve Button
3. Allen Wrench (3/16 in.)
4. Wrench (9/16 in.)
5. Intake Valve Stem

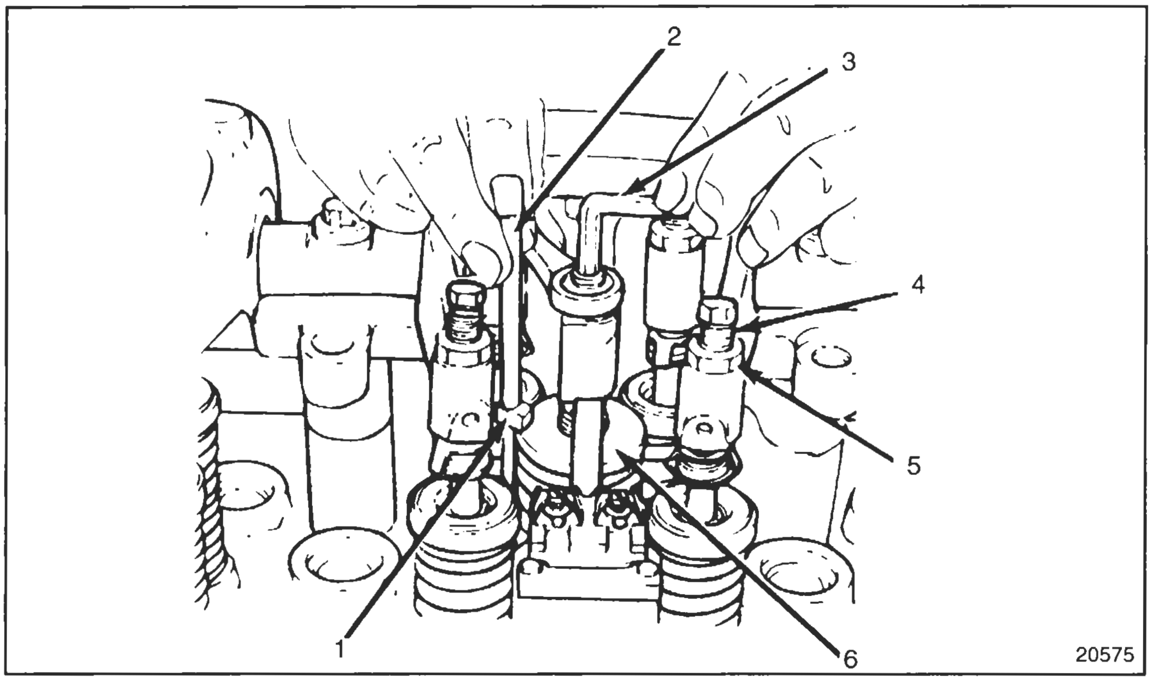
Figure 12–6 Valve Clearance Adjustment

8. Tighten the locknut to 41–47 N·m (30–35 lb·ft) and remove the feeler gage. Reinsert the feeler gage to ensure that the adjustment did not change when the locknut was tightened. Readjust as necessary.
9. The exhaust valves are adjusted the same way as the intake valves, except use a 0.660 mm (.026 in.) feeler gage.

It is normal for tune-up settings to vary, even when using the correct setting procedures. Some items influencing tune-up measurements are different gages, individuals and mechanical variations.

NOTE:
When setting valve lash clearance or injector height, always set them to the dimension shown in text (nominal dimensions)

10. Complete the adjustment of all four valves (two intake, two exhaust) for that cylinder before proceeding to step 11.
11. Refer to the Timing Circle Chart and note the cylinder number in parentheses, directly under the cylinder that just received the valve lash adjustment. See Figure 12-5.
12. Adjust the fuel injector height for the cylinder indicated on the chart in parentheses, see Figure 12-5, by placing the small end of the height gage in the hole provided in the fuel injector body, with the flat of the gage toward the fuel injector plunger. See Figure 12-7. The injector setting dimension for Series 50 engines with DDEC II is 78.8 mm (3.102 in.) and DDEC III Series 50 engines with is 78.2 mm (3.08 in.).

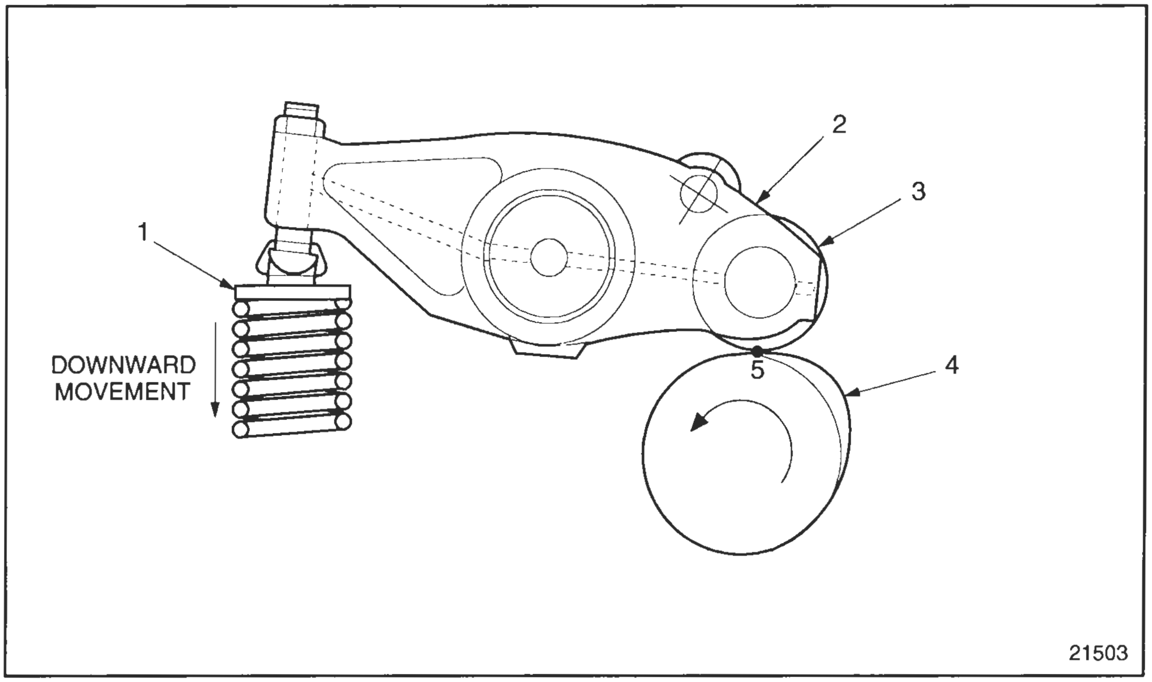


1. Height Gage Flag
2. Height Gage
3. Allen Wrench (3/16 in.)
4. Set Screw
5. Locknut
6. Fuel Injector Follower

Figure 12–7 Fuel Injector Height Adjustment

13. Loosen the fuel injector rocker arm locknut and turn the adjusting set screw until the extended part (flag) of the gage will just pass over the top of the injector follower. An accurate "feel" will be developed. The objective is to adjust all four injectors to the same feel.
14. Tighten the locknut to 41–47 N·m (30–35 lb·ft). Check the adjustment with the height gage and, if necessary, readjust the set screw. Remove the height gage.
15. Refer to the Timing Circle Chart. See Figure 12-5 and follow the arrow to the next cylinder in the adjustment sequence.

16. Bar the engine over in the direction of normal rotation until the injector follower of the next cylinder in the adjustment sequence begins its downward motion, see Figure 12–8.



1. Injector Follower
2. Injector Rocker Arm Assembly
3. Injector Roller
4. Injector Cam Lobe
5. Point on the Camshaft Lobe that First Produces Downward Motion of the Injector Follower

Figure 12–8 Injector Followers Downward Stroke

17. Repeat the valve adjustment and fuel injector height adjustment step 5. through step 15. until all the valves and fuel injectors have been adjusted.
18. Replace the engine rocker cover. Refer to section 1.6.
19. Reconnect starting power to the engine.

12.2.1 SLAVE PISTON ADJUSTMENT (JAKE BRAKE® LASH)

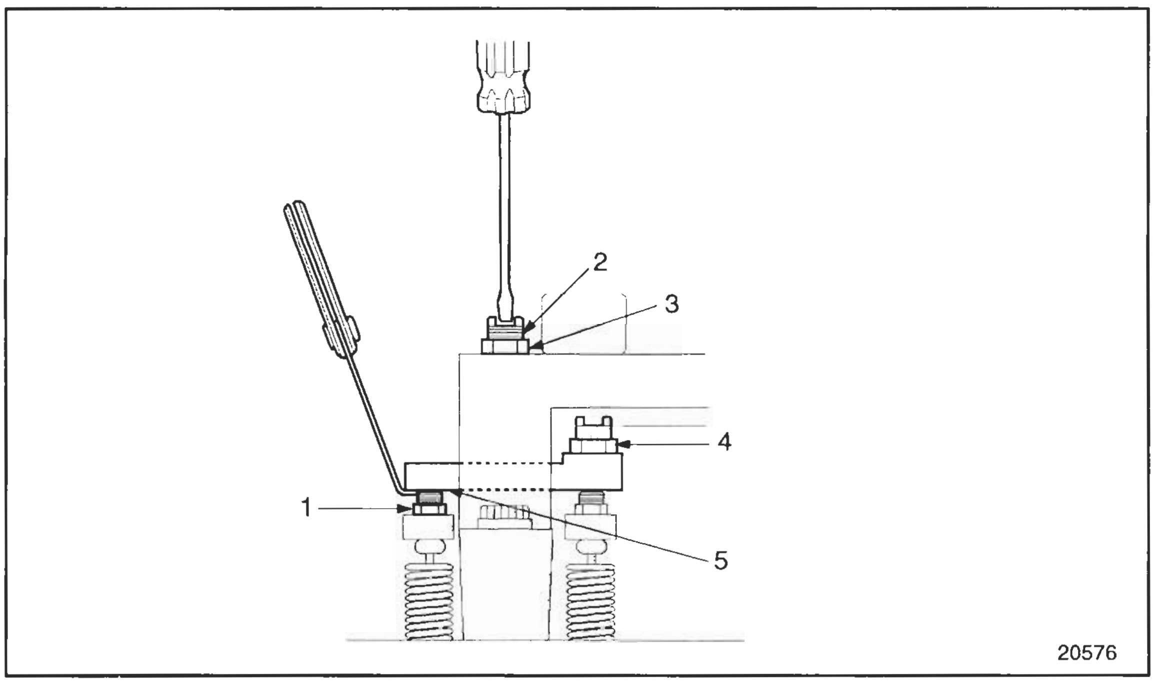
Adjust slave piston as follows:

NOTICE:
The slave piston adjustment procedure must be strictly followed. Failure to use the proper adjustment procedure will result in poor engine brake performance, serious engine damage, or both.

NOTE:
Make the following adjustment with the engine stopped and cold with oil temperature 140°F (60°C) or below. The exhaust valves on the cylinder to be adjusted must be in the closed position (rocker arm loose).

1. Back out the leveling screw in the slave piston assembly until the end of the screw is beneath the surface of the bridge in the slave piston assembly. See Figure 12-9.

NOTE:
The leveling screw is the screw located in the bridge member of the slave piston assembly.



1. Exhaust Valve Adjusting Screw
2. Slave Piston Screw
3. Locknut
4. Leveling Screw
5. Bridge

Figure 12–9 Adjusting Slave Piston Screw

2. Place a 0.660 mm (0.026 in.) feeler gage between the solid side of the bridge (the side without the leveling screw) and the exhaust rocker arm adjusting screw.

NOTE:
The slave piston adjusting screws used in the Series 50 Engine Brake prior to August 1994 were RESET SCREWS. Reset screws are not to be disassembled in the field. Effective with August 1994 engines, reset screw assemblies were replaced with Power Lash assemblies.

3. Turn the slave piston adjusting screw clockwise until a light drag is felt on the feeler gage.
4. Hold the screw in this position and tighten the locknut to 35 N·m (25 lb·ft).
5. Follow the same procedure and set the same clearance between the slave piston leveling screw and the rocker arm adjusting screw. See Figure 12–10.

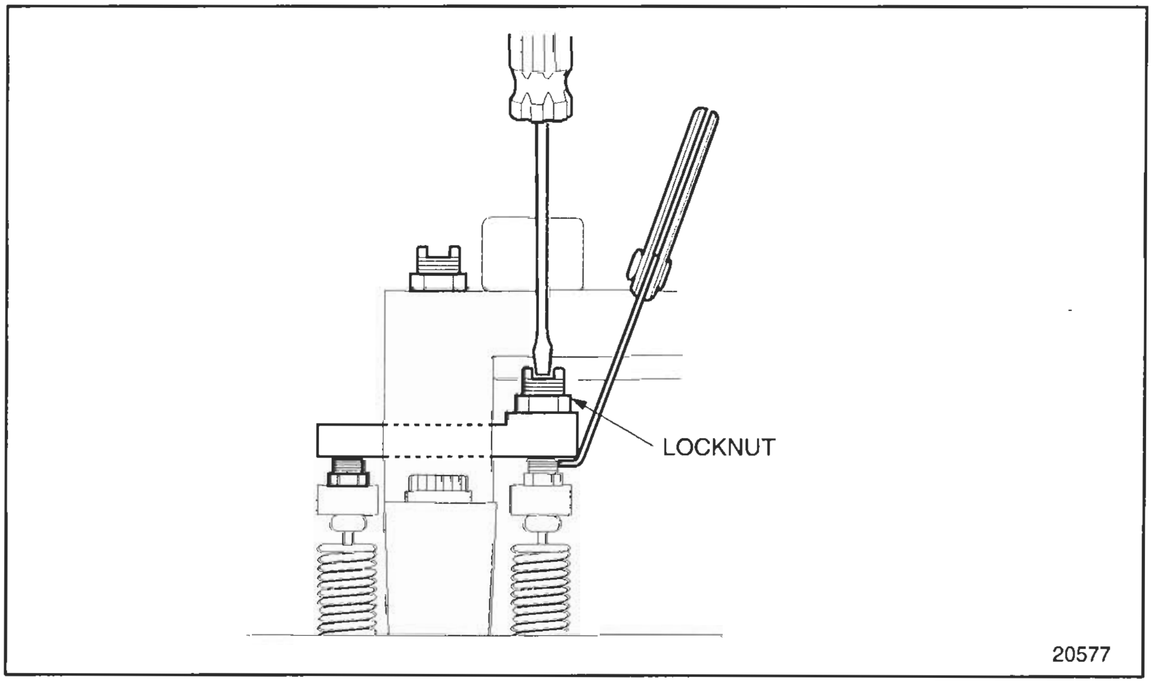


Figure 12–10 Adjusting Leveling Screw

6. Hold the leveling screw in this position and tighten the locknut to 47 N·m (35 lb·ft).
7. Repeat the adjustment procedures in step 1. through step 6. for the remaining cylinders. Rotate the engine when necessary to put the exhaust valves in the closed position for slave piston adjustment.

12.A ADDITIONAL INFORMATION

Description | Page

SERVICE TOOLS

Listed in Table 12–1 are the service tools used in this section.

Tool No.	Tool Name
J 35637–A	Injector Timing Gauge (1993 & Prior)
J 39697	Fuel Injector Timing Gauge
J 26554–A	Turbocharger Compressor Inlet Shield

Table 12–1 Service Tools

13 PREVENTIVE MAINTENANCE

13.1 MAINTENANCE OVERVIEW

The preventive maintenance schedule is intended as a guide for establishing a preventive maintenance schedule. The suggestions and recommendations for preventive maintenance should be followed as closely as possible to obtain long life and best performance from the Series 50 Engine. The intervals indicated are time or miles of actual operation.

The time or mileage increments shown apply only to the maintenance function described. These functions should be coordinated with other regularly scheduled maintenance such as chassis lubrication.

The daily instructions pertain to routine or daily starting of an engine and not to a new engine or one that has not been operated for a considerable period of time. For new or stored engines, carry out the instructions given under "Preparation for a First Time Start." Refer to section 11.1.

The daily maintenance of Series 50 engines is the same for all applications. Refer to section 13.2. Periodic maintenance of Series 50 engines is dependent on the application. For engines installed in stationary and industrial applications, refer to section 13.4. For engines installed in vehicles, refer to section 13.3.

13.2 DAILY MAINTENANCE – ALL APPLICATIONS

The following items need to be inspected, serviced, corrected or replaced on a daily basis, as necessary:

- ❑ Lubricating oil, refer to section 13.5.1
- ❑ Fuel tank, refer to section 13.5.2
- ❑ Fuel lines and flexible hoses, refer to section 13.5.3
- ❑ Cooling system, refer to section 13.5.4
- ❑ Turbocharger, refer to section 13.5.5

13.3 MAINTENANCE OF VEHICLE ENGINES

Vehicle engine components must be maintained at various intervals.

13.3.1 6,000 Mile (10,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.2 7,500 Mile (12,000 km) Interval Maintenance

Every 7,500 miles (12,000 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ❑ Battery, refer to section 13.5.6
- ❑ Drive belts, refer to section 13.5.7
- ❑ Air compressor, refer to section 13.5.8

13.3.3 12,000 Mile (19,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.4 15,000 Mile (24,000 km) or 6 Month Interval Maintenance

The following components must be replaced every 15,000 miles (24,000 km) or 6 months.

- ❑ Air cleaner, refer to section 13.5.9
- ❑ Lubricating oil, refer to section 13.5.1
- ❑ Lubricating oil filter, refer to section 13.5.10
- ❑ Fuel filter, refer to section 13.5.11
- ❑ Coolant filter and inhibitor, refer to section 13.5.12

13.3.5 18,000 Mile (30,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.6 24,000 Mile (39,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.7 30,000 Mile (48,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.8 30,000 Mile (48,000 km) or 12 Month Interval Maintenance

Every 30,000 miles (48,000 km) or 12 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ❑ Fuel tank, refer to section 13.5.2
- ❑ Drive belts, refer to section 13.5.7
- ❑ Air compressor, refer to section 13.5.8
- ❑ Air system, refer to section 13.5.14
- ❑ Exhaust system, refer to section 13.5.15
- ❑ Engine (steam clean), refer to section 13.5.16
- ❑ Radiator and air–to–air charge cooler, refer to section 13.5.17
- ❑ Battery charging alternator, refer to section 13.5.19

Likewise, the following components must be replaced every 30,000 miles (48,000 km) or 12 months.

- ❑ Lubricating oil, refer to section 13.5.1
- ❑ Lubricating oil filter, refer to section 13.5.10
- ❑ Fuel filter, refer to section 13.5.11
- ❑ Coolant filter and inhibitor, refer to section 13.5.12

13.3.9 36,000 Mile (58,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.10 42,000 Mile (68,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.1145,000 Mile (72,000 km) or 18 Month Interval Maintenance

Every 45,000 miles (72,000 km) or 18 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ❑ Drive belts, refer to section 13.5.7
- ❑ Air compressor, refer to section 13.5.8
- ❑ Air system, refer to section 13.5.14
- ❑ Exhaust system, refer to section 13.5.15
- ❑ Valve lash and injector height, refer to section 13.5.25

Likewise, the following components must be replaced every 45,000 miles (72,000 km) or 18 months.

- ❑ Lubricating oil, refer to section 13.5.1
- ❑ Lubricating oil filter, refer to section 13.5.10
- ❑ Fuel filter, refer to section 13.5.11
- ❑ Coolant filter and inhibitor, refer to section13.5.12

13.3.12 48,000 Mile (77,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.13 54,000 Mile (87,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.14 60,000 Mile (97,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.15 60,000 Mile (96,000 km) or 24 Month Interval Maintenance

Every 60,000 miles (96,000 km) or 24 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ❑ Fuel tank, refer to section 13.5.2
- ❑ Cooling system, refer to section 13.5.4
- ❑ Drive belts, refer to section 13.5.7
- ❑ Air compressor, refer to section 13.5.8
- ❑ Air system, refer to section 13.5.14
- ❑ Exhaust system, refer to section 13.5.15
- ❑ Engine (steam clean), refer to section 13.5.16
- ❑ Radiator and air–to–air charge cooler, refer to section 13.5.17
- ❑ Oil pressure, refer to section 13.5.18
- ❑ Battery charging alternator, refer to section 13.5.19
- ❑ Engine and transmission mounts, refer to section 13.5.20
- ❑ Crankcase pressure, refer to section 13.5.21
- ❑ Thermostats and seals, refer to section 13.5.23
- ❑ Crankcase breather, refer to section 13.5.24
- ❑ Valve lash and injector height, refer to section 13.5.25

Likewise, the following components must be replaced every 60,000 miles (96,000 km) or 24 months.

- ❑ Lubricating oil, refer to section 13.5.1
- ❑ Lubricating oil filter, refer to section 13.5.10
- ❑ Fuel filter, refer to section 13.5.11
- ❑ Coolant filter and inhibitor, refer to section 13.5.12

13.3.16 66,000 Mile (106,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.17 72,000 Mile (116,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.18 75,000 Mile (120,000 km) or 30 Month Interval Maintenance

Every 75,000 miles (120,000 km) or 30 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ❑ Drive belts, refer to section 13.5.7
- ❑ Air compressor, refer to section 13.5.8
- ❑ Air system, refer to section 13.5.14
- ❑ Exhaust system, refer to section 13.5.15

Likewise, the following components must be replaced every 75,000 miles (120,000 km) or 30 months.

- ❑ Lubricating oil, refer to section 13.5.1
- ❑ Lubricating oil filter, refer to section 13.5.10
- ❑ Fuel filter, refer to section 13.5.11
- ❑ Coolant filter and inhibitor, refer to section 13.5.12

13.3.19 78,000 Mile (126,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.20 84,000 Mile (135,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.21 90,000 Mile (145,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.22 90,000 Mile (144,000 km) or 36 Month Interval Maintenance

Every 90,000 miles (144,000 km) or 36 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ❑ Fuel tank, refer to section 13.5.2
- ❑ Drive belts, refer to section 13.5.7
- ❑ Air compressor, refer to section 13.5.8
- ❑ Air system, refer to section 13.5.14
- ❑ Exhaust system, refer to section 13.5.15
- ❑ Engine (steam clean), refer to section 13.5.16
- ❑ Radiator and air–to–air charge cooler, refer to section 13.5.17
- ❑ Battery charging alternator, refer to section 13.5.19

Likewise, the following components must be replaced every 90,000 miles (144,000 km) or 36 months.

- ❑ Lubricating oil, refer to section 13.5.1
- ❑ Lubricating oil filter, refer to section 13.5.10
- ❑ Fuel filter, refer to section 13.5.11
- ❑ Coolant filter and inhibitor, refer to section 13.5.12

13.3.23 96,000 Mile (154,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.24 102,000 Mile (164,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.25 105,000 Mile (168,000 km) or 42 Month Interval Maintenance

Every 105,000 miles (168,000 km) or 42 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ❑ Drive belts, refer to section 13.5.7
- ❑ Air compressor, refer to section 13.5.8
- ❑ Air system, refer to section 13.5.14
- ❑ Exhaust system, refer to section 13.5.15

Likewise, the following components must be replaced every 105,000 miles (168,000 km) or 42 months.

- ❑ Lubricating oil, refer to section 13.5.1
- ❑ Lubricating oil filter, refer to section 13.5.10
- ❑ Fuel filter, refer to section 13.5.11
- ❑ Coolant filter and inhibitor, refer to section 13.5.12

13.3.26 108,000 Mile (174,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.27 114,000 Mile (183,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.28 120,000 Mile (193,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.29 120,000 Mile (192,000 km) or 48 Month Interval Maintenance

Every 120,000 miles (192,000 km) or 48 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ❑ Fuel tank, refer to section 13.5.2
- ❑ Cooling system, refer to section 13.5.4
- ❑ Air compressor, refer to section 13.5.8
- ❑ Air system, refer to section 13.5.14
- ❑ Exhaust system, refer to section 13.5.15
- ❑ Engine (steam clean), refer to section 13.5.16
- ❑ Radiator and air–to–air charge cooler, refer to section 13.5.17
- ❑ Oil pressure, refer to section 13.5.18
- ❑ Battery charging alternator, refer to section 13.5.19
- ❑ Engine and transmission mounts, refer to section 13.5.20
- ❑ Crankcase pressure, refer to section 13.5.21
- ❑ Thermostats and seals, refer to section 13.5.23
- ❑ Crankcase breather, refer to section 13.5.24

Likewise, the following components must be replaced every 120,000 miles (192,000 km) or 48 months.

- ❑ Drive belts, refer to section 13.5.7
- ❑ Lubricating oil, refer to section 13.5.1
- ❑ Lubricating oil filter, refer to section 13.5.10
- ❑ Fuel filter, refer to section 13.5.11
- ❑ Coolant filter and inhibitor, refer to section 13.5.12

13.3.30 126,000 Mile (203,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.31 132,000 Mile (213,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.32 135,000 Mile (216,000 km) or 54 Month Interval Maintenance

Every 135,000 miles (216,000 km) or 54 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ❑ Drive belts, refer to section 13.5.7
- ❑ Air compressor, refer to section 13.5.8
- ❑ Air system, refer to section 13.5.14
- ❑ Exhaust system, refer to section 13.5.15

Likewise, the following components must be replaced every 135,000 miles (216,000 km) or 54 months.

- ❑ Lubricating oil, refer to section 13.5.1
- ❑ Lubricating oil filter, refer to section 13.5.10
- ❑ Fuel filter, refer to section 13.5.11
- ❑ Coolant filter and inhibitor, refer to section 13.5.12

13.3.33 138,000 Mile (222,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.34 144,000 Mile (232,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.35 150,000 Mile (242,000 km) Interval Maintenance (City Coach Only)

The oil must be changed on a City Coach Engine.

13.3.36 150,000 Mile (240,000 km) or 60 Month Interval Maintenance

Every 150,000 miles (240,000 km) or 60 months, the following components must be inspected, serviced, corrected or replaced as necessary.

- ❑ Fuel tank, refer to section 13.5.2
- ❑ Drive belts, refer to section 13.5.7
- ❑ Air compressor, refer to section 13.5.8
- ❑ Air system, refer to section 13.5.14
- ❑ Exhaust system, refer to section 13.5.15
- ❑ Engine (steam clean), refer to section 13.5.16
- ❑ Radiator and air–to–air charge cooler, refer to section 13.5.17
- ❑ Battery charging alternator, refer to section 13.5.19

Likewise, the following components must be replaced every 150,000 miles (240,000 km) or 60 months.

- ❑ Lubricating oil, refer to section 13.5.1
- ❑ Lubricating oil filter, refer to section 13.5.10
- ❑ Fuel filter, refer to section 13.5.11
- ❑ Coolant filter and inhibitor, refer to section 13.5.12

13.4 MAINTENANCE OF ENGINES USED IN STATIONARY AND INDUSTRIAL APPLICATIONS

Engine components used in stationary and industrial applications must be maintained at various intervals.

13.4.1 100 Hours (3,000 Miles–4,800 km) Maintenance

Every 100 hours (3,000 miles–4,800 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ❑ Battery, refer to section 13.5.6
- ❑ Drive belts, refer to section 13.5.7

13.4.2 150 Hours (4,500 miles–7,200 km) Maintenance

Every 150 hours (4,500 miles–7,200 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ❑ Air compressor, refer to section 13.5.8
- ❑ Air cleaner, refer to section 13.5.9

Likewise, the following components must be replaced every 150 hours (4,500 miles–7,200 km).

- ❑ Lubricating oil, refer to section 13.5.1
- ❑ Lubricating oil filter, refer to section 13.5.10
- ❑ Fuel filter, refer to section 13.5.11
- ❑ Coolant filter and inhibitor, refer to section 13.5.12

13.4.3 300 Hours (9,000 miles–14,400 km) Maintenance

Every 300 hours (9,000 miles–14,400 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ❑ Fuel tank, refer to section 13.5.2
- ❑ Air compressor, refer to section 13.5.8
- ❑ Air system, refer to section 13.5.14
- ❑ Exhaust system, refer to section 13.5.15
- ❑ Engine (steam clean), refer to section 13.5.16
- ❑ Radiator and air–to–air charge cooler, refer to section 13.5.17
- ❑ Battery charging alternator, refer to section 13.5.19

Likewise, the following components must be replaced every 300 hours (9,000 miles–14,000 km).

- ❑ Lubricating oil, refer to section 13.5.1
- ❑ Lubricating oil filter, refer to section 13.5.10
- ❑ Fuel filter, refer to section 13.5.11
- ❑ Coolant filter and inhibitor, refer to section 13.5.12

13.4.4 450 Hours (13,500 miles–21,600 km) Maintenance

Every 450 hours (13,500 miles–21,600 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ❑ Air compressor, refer to section 13.5.8
- ❑ Air system, refer to section 13.5.14
- ❑ Exhaust system, refer to section 13.5.15

Likewise, the following components must be replaced every 450 hours (13,500 miles–21,600 km).

- ❑ Lubricating oil, refer to section 13.5.1
- ❑ Lubricating oil filter, refer to section 13.5.10
- ❑ Fuel filter, refer to section 13.5.11
- ❑ Coolant filter and inhibitor, refer to section 13.5.12

13.4.5 600 Hours (18,000 miles–28,800 km) Maintenance

Every 600 hours (18,000 miles–28,800 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ❑ Fuel tank, refer to section 13.5.2
- ❑ Air compressor, refer to section 13.5.8
- ❑ Air system, refer to section 13.5.14
- ❑ Exhaust system, refer to section 13.5.15
- ❑ Engine (steam clean), refer to section 13.5.16
- ❑ Radiator and air–to–air charge cooler, refer to section 13.5.17
- ❑ Oil pressure, refer to section 13.5.18
- ❑ Battery charging alternator, refer to section 13.5.19
- ❑ Engine and transmission mounts, refer to section 13.5.20
- ❑ Crankcase pressure, refer to section 13.5.21
- ❑ Thermostats and seals, refer to section 13.5.23
- ❑ Crankcase breather, refer to section 13.5.24

Likewise, the following components must be replaced every 600 hours (18,000 miles–28,800 km).

- ❑ Lubricating oil, refer to section 13.5.1
- ❑ Lubricating oil filter, refer to section 13.5.10
- ❑ Fuel filter, refer to section 13.5.11
- ❑ Coolant filter and inhibitor, refer to section 13.5.12

13.4.6 750 Hours (22,500 miles–36,000 km) Maintenance

Every 750 hours (22,500 miles–36,000 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ❑ Cooling system, refer to section 13.5.4
- ❑ Air compressor, refer to section 13.5.8
- ❑ Air system, refer to section 13.5.14
- ❑ Exhaust system, refer to section 13.5.15

Likewise, the following components must be replaced every 750 hours (22,500 miles–36,000 km).

- ❑ Lubricating oil, refer to section 13.5.1
- ❑ Lubricating oil filter, refer to section 13.5.10
- ❑ Fuel filter, refer to section 13.5.11
- ❑ Coolant filter and inhibitor, refer to section 13.5.12

13.4.7 900 Hours (27,000 miles–43,200 km) Maintenance

Every 900 hours (27,000 miles–43,200 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ❑ Fuel tank, refer to section 13.5.2
- ❑ Air compressor, refer to section 13.5.8
- ❑ Air system, refer to section 13.5.14
- ❑ Exhaust system, refer to section 13.5.15
- ❑ Engine (steam clean), refer to section 13.5.16
- ❑ Radiator and air–to–air charge cooler, refer to section 13.5.17
- ❑ Battery charging alternator, refer to section 13.5.19

Likewise, the following components must be replaced every 900 hours (27,000 miles–43,200 km).

- ❑ Lubricating oil, refer to section 13.5.1
- ❑ Lubricating oil filter, refer to section 13.5.10
- ❑ Fuel filter, refer to section 13.5.11
- ❑ Coolant filter and inhibitor, refer to section 13.5.12

13.4.8 1,050 Hours (31,500 miles–50,400 km) Maintenance

Every 1,050 hours (31,500 miles–50,400 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ❑ Air compressor, refer to section 13.5.8
- ❑ Air system, refer to section 13.5.14
- ❑ Exhaust system, refer to section 13.5.15
- ❑ Fan Hub, refer to section 13.5.22

Likewise, the following components must be replaced every 1,050 hours (31,500 miles–50,400 km).

- ❑ Lubricating oil, refer to section 13.5.1
- ❑ Lubricating oil filter, refer to section 13.5.10
- ❑ Fuel filter, refer to section 13.5.11
- ❑ Coolant filter and inhibitor, refer to section 13.5.12

13.4.9 1,200 Hours (36,000 miles–57,600 km) Maintenance

Every 1,200 hours (36,000 miles–57,600 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ❑ Fuel tank, refer to section 13.5.2
- ❑ Air compressor, refer to section 13.5.8
- ❑ Air system, refer to section 13.5.14
- ❑ Exhaust system, refer to section 13.5.15
- ❑ Engine (steam clean), refer to section 13.5.16
- ❑ Radiator and air-to-air charge cooler, refer to section 13.5.17
- ❑ Oil pressure, refer to section 13.5.18
- ❑ Battery charging alternator, refer to section 13.5.19
- ❑ Engine and transmission mounts, refer to section 13.5.20
- ❑ Crankcase pressure, refer to section 13.5.21
- ❑ Thermostats and seals, refer to section 13.5.22
- ❑ Crankcase breather, refer to section 13.5.23

Likewise, the following components must be replaced every 1,200 hours (36,000 miles–57,600 km).

- ❑ Lubricating oil, refer to section 13.5.1
- ❑ Lubricating oil filter, refer to section 13.5.10
- ❑ Fuel filter, refer to section 13.5.11
- ❑ Coolant filter and inhibitor, refer to section 13.5.12

13.4.10 1,350 Hours (40,500 miles–64,800 km) Maintenance

Every 1,350 hours (40,500 miles–64,800 km), the following components must be inspected, serviced, corrected or replaced as necessary.

- ❑ Air compressor, refer to section 13.5.8
- ❑ Air system, refer to section 13.5.14
- ❑ Exhaust system, refer to section 13.5.15

Likewise, the following components must be replaced every 1,350 hours (40,500 miles–64,800 km).

- ❑ Lubricating oil, refer to section 13.5.1
- ❑ Lubricating oil filter, refer to section 13.5.10
- ❑ Fuel filter, refer to section 13.5.11
- ❑ Coolant filter and inhibitor, refer to section 13.5.12

13.4.11 1,500 Hours (45,000 miles–72,000 km) Maintenance

Every 1,500 hours (45,000 miles–72,000 km), the following components must be inspected, serviced, corrected or replaced as necessary.

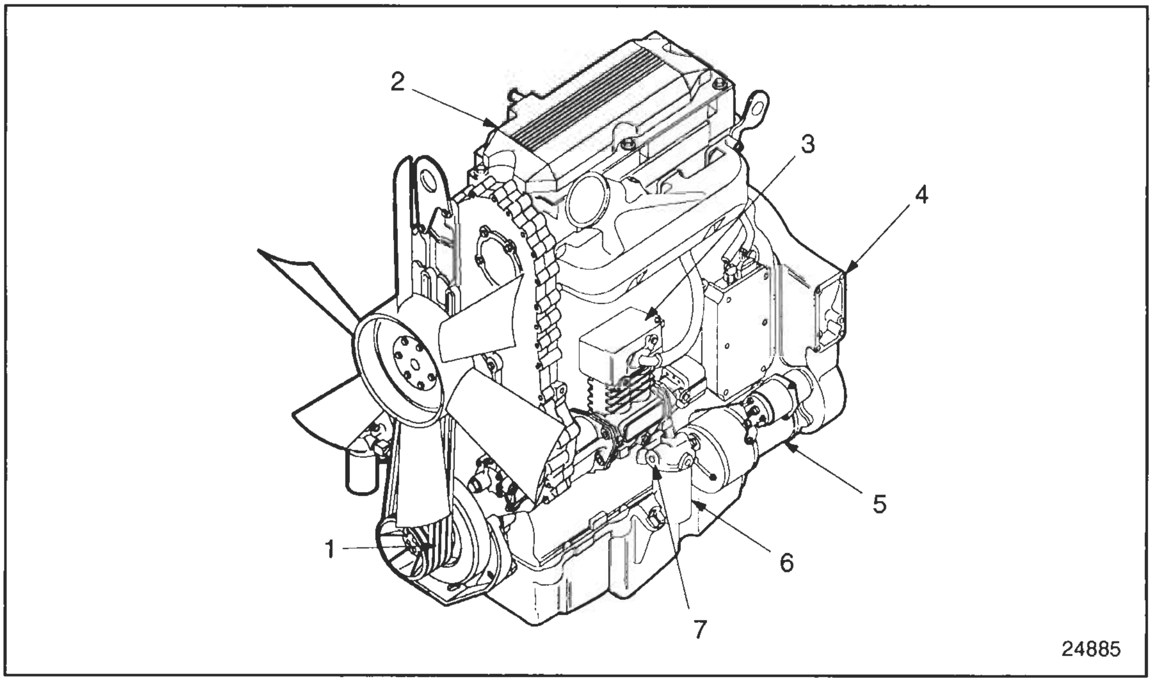
- ❑ Fuel tank, refer to section 13.5.2
- ❑ Cooling system, refer to section 13.5.4
- ❑ Air compressor, refer to section 13.5.8
- ❑ Air system, refer to section 13.5.14
- ❑ Exhaust system, refer to section 13.5.15
- ❑ Engine (steam clean), refer to section 13.5.16
- ❑ Radiator and air-to-air charge cooler, refer to section 13.5.17
- ❑ Battery charging alternator, refer to section 13.5.19

Likewise, the following components must be replaced every 1500 hours (45,000 miles–72,000 km).

- ❑ Lubricating oil, refer to section 13.5.1
- ❑ Lubricating oil filter, refer to section 13.5.10
- ❑ Fuel filter, refer to section 13.5.11
- ❑ Coolant filter and inhibitor, refer to section 13.5.12

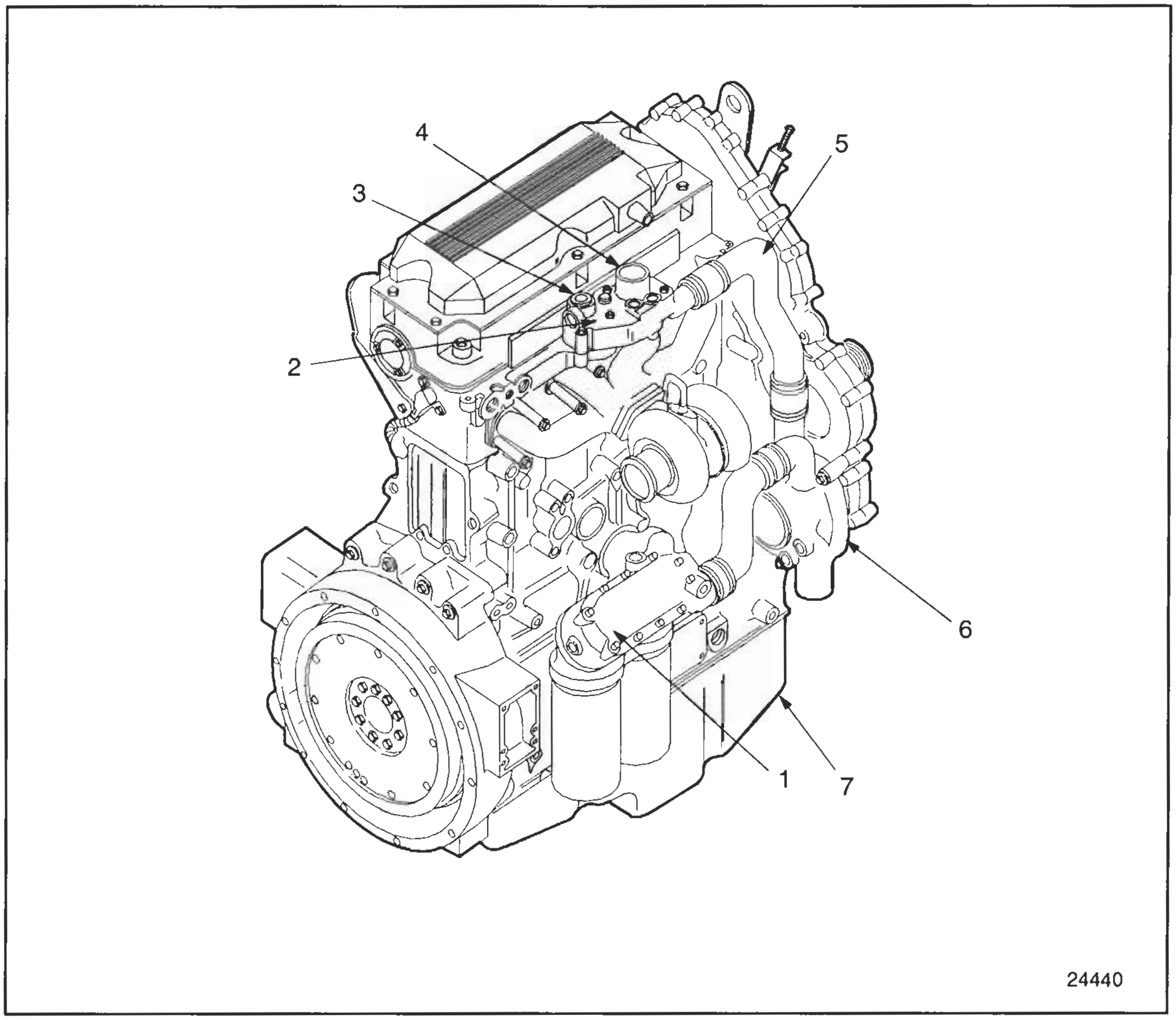
13.5 DESCRIPTION OF MAINTENANCE ITEMS

For locations of components and systems to be maintained, see Figure 13-1, and see Figure 13-2.



1. Drive Belts
2. Rocker Cover
3. Air Compressor
4. Transmission Mounts
5. Cranking Motor
6. Fuel Filter
7. Fuel Filter Fitting

Figure 13–1 Preventive Maintenance Service Items



1. Oil Cooler
2. Thermostat Housing
3. Thermostat Vent
4. Thermostats and Seals
5. Water Bypass Tube
6. Water Pump
7. Oil Pan

Figure 13–2 Preventive Maintenance Service Items

13.5.1 Lubricating Oil

Check the lubricating oil level with the engine stopped and the vehicle on level ground. If the engine has just been stopped and is warm, wait approximately 20 minutes to allow the oil to drain back to the oil pan. Add the proper grade oil as required to maintain the correct level on the dipstick. Refer to section 5.2.

NOTE:
Oil may be blown out through the crankcase breather if the crankcase is overfilled.

Make a visual check for oil leaks around the filters and the external oil lines.

Select the proper grade of oil. Refer to section 5.2.

Change the lubricating oil as follows:

1. Position the vehicle or equipment on level ground.
2. If the engine is cold, run it until it is warm.

NOTE:
If the lubricating oil is drained immediately after an engine has been run for some time, most of the sediment will be in suspension and will drain readily.

NOTICE:
When removing or installing a side plug, hold the flats of the insert with a 2 1/8 in., or larger, open end adjustable wrench to keep it from turning. If the insert is loosened, it may be necessary to remove the oil pan, and retighten the nut to prevent a possible oil leak.

3. Remove drain plug on the bottom of oil pan. Drain lube oil into a suitable container. *Always dispose of used lubrication oil in an environmentally responsible manner, according to EPA and state recommendations.*
4. Coat drain plug(s) with Loctite PT7271 sealant (or equivalent). Install and tighten to 45–56 N·m (33–41 lb·ft).

To replace the lube oil filters, perform the following procedure:

1. Remove the spin–on filter cartridges using strap wrench tool J 29917 (or equivalent) and a 1/2 in. drive socket wrench and extension.
2. Dispose of the used oil and filters in an environmentally responsible manner, according to EPA and state recommendations.
3. Clean the filter adaptor with a clean, lint–free cloth.
4. Lightly coat the filter gaskets (seals) with clean engine oil.
5. Start the new filters on the adaptor, and tighten by hand until the gaskets touch the mounting adaptor head. **Tighten full flow filters an additional two–thirds turn by hand.**

Add oil as required to bring the level to the "full" mark on the dipstick. Twenty two quarts (21 L) are required when the filters are not changed.

Start and run the engine for a short period, and check for leaks. After leaks have been corrected, stop the engine long enough for oil to drain back to the crankcase (approximately 20 minutes). Add oil as required to bring the level to the proper mark on the dipstick.

13.5.2 Fuel Tanks

Keep the fuel tank filled to reduce the condensation to a minimum. Select the proper grade of fuel in accordance with the Fuel Specifications. Refer to section 5.1.

Open the drain at the bottom of the fuel tank every 30,000 miles/48,000 km (300 hours for industrial applications), to drain off any water and sediment.

Every 12 months or 60,000 miles/96,000 km (600 hours for industrial applications), whichever comes first, tighten all fuel tank mountings and brackets (refer to OEM maintenance guidelines). At the same time, check the seal in the fuel tank cap, the breather hole in the cap and the condition of the flexible fuel lines. Repair or replace the parts as necessary (refer to OEM maintenance guidelines).

The most common form of diesel fuel contamination is water. Water is harmful to the fuel system in itself, but it also promotes the growth of microbiological organizations (microbes). These microbes clog fuel filters with a "slime" and restrict fuel flow.

Condensation is particularly prevalent on units that stand idle for extended periods of time. Ambient temperature changes cause condensation in partially filled fuel tanks.

Units in storage are particularly susceptible to microbe growth. The microbes live in the fuel–water interface. They need both liquids to survive. These microbes find excellent growth conditions in the dark, quiet, non-turbulent nature of the fuel tank.

Microbe growth can be eliminated through the use of commercially available biocides. There are two basic types on the market:

- ❑ The water soluble type treats **only the tank** where it is introduced. Microbe growth can start again if fuel is transferred from a treated to an untreated tank.
- ❑ The diesel fuel soluble type, such as "Biobor" manufactured by U.S. Borax (or equivalent), treats the fuel itself, and therefore, the entire fuel system.

Any units that will sit idle for extended periods, or any units being stored, should be treated as follows: Add the biocide according to the manufacturer's instructions. This operation is most effective when performed as the tank is being filled. Add dry gas (isopropyl alcohol) in the correct proportions.

If the fuel tanks were previously filled, add the chemicals and stir with a clean rod.

13.5.3 Fuel Lines and Flexible Hoses

Make a visual check for fuel leaks at all engine-mounted fuel lines and connections, and at the fuel tank suction and return lines. Since fuel tanks are susceptible to road hazards, leaks in this area may best be detected by checking for accumulation of fuel under the tanks.

The performance of engine and auxiliary equipment is greatly dependent on the ability of flexible hoses to transfer lubricating oil, air, coolant and fuel oil. Diligent maintenance of hoses is an important step in ensuring efficient, economical and safe operation of the engine and related equipment.

Check hoses daily as part of the pre-start up inspection. Examine hoses for leaks and check all fittings, clamps and ties carefully. Be sure that hoses are not resting on or touching shafts, couplings, heated surfaces, including exhaust manifolds, any sharp edges or other obviously hazardous areas. Since all machinery vibrates and moves to a certain extent, clamps and ties can fatigue with age. To ensure continued proper support, inspect fasteners frequently and tighten or replace them, as necessary (refer to OEM maintenance guidelines).

Investigate leaks immediately to determine if hoses have ruptured or worn through. Take corrective action immediately. Leaks are not only potentially detrimental to machine operation, but they also result in added expense caused by the need to replace lost fluids.

CAUTION:

Personal injury and/or property damage may result from fire due to the leakage of flammable fluids such as fuel or lube oil.

A hose has a finite service life. The service life of a hose is determined by the temperature and pressure of the air or fluid within it, its time in service, its mounting, the ambient temperatures and amount of flexing and vibration it is subjected to. With this in mind, all hoses should be thoroughly inspected annually. Look for cover damage or indications of damaged, twisted, worn, crimped, brittle, cracked or leaking lines. Hoses having the outer cover worn through or damaged metal reinforcement should be considered unfit for further service.

All hoses in or out of machinery should be replaced during major overhaul or after a maximum of five years service.

13.5.4 Cooling System

Check the coolant level daily. Be sure it is within 2 in. (50 mm) of the filler neck or vehicle manufacturer's recommendation. Add coolant, as necessary. Refer to section 5. **Do not overfill.**

Make a visual check for cooling system leaks. Check for an accumulation of coolant beneath the vehicle during periods when the engine is running and when the engine is stopped.

NOTE:
In order to ensure the integrity of the cooling system, it is recommended that a periodic cooling system pressure check be performed. Pressurize the cooling system 103–138 kPa (15–20 lb/in.^{2}) using radiator cap and cooling system tester, J 24460–01. Do not exceed 138 kPa (20 lb/in.^{2}). Any measurable drop in pressure may indicate an external/internal leak. Whenever the oil pan is removed, the cooling system should be pressure checked as a means of identifying any internal coolant system leaks.

Clean the cooling system every 24 months using a good radiator cleaning combination in accordance with the instructions on the container. After the cleaning operation, rinse the cooling system thoroughly with fresh water. Then fill the system with the proper anti-freeze/water mixture and pre-charge of inhibitors.

Inspect all of the cooling system hoses at least once every 30,000 miles/48,000 km (300 hours for industrial applications) to be sure the clamps are tight and properly seated on the hoses and to check for signs of deterioration. Replace the hoses, if necessary. Refer to OEM maintenance guidelines.

Drain the engine coolant as follows:

1. Allow engine to cool.

CAUTION:

Do not remove the pressure control cap from the radiator or attempt to drain the coolant until the engine has cooled. Once the engine has cooled, use extreme caution when removing the cap. The sudden release of pressure from a heated cooling system can result in a loss of coolant and possible personal injury (scalding, eye injury, etc.) from the hot liquid.

2. Remove drain plugs from the bottom of water pump, at the right rear of the engine, and at the bottom of the thermostat housing.
3. Remove radiator pressure cap.
4. Open valve at bottom of radiator.
5. Collect used antifreeze in a suitable container, and dispose of the solution in an environmentally responsible manner, according to state and federal (EPA) recommendations.

6. Replace all drain plugs, and close any drain valves.
7. Refill the system with proper antifreeze and clean soft water mixture.
8. Purge entrapped air by allowing the engine to warm–up without the pressure cap installed. With the transmission in neutral, increase engine speed above 1000 r/min. Add coolant as required.
9. Allow engine to cool.
10. Install the pressure cap after filling the coolant level to the bottom of the radiator filler neck.

If the cooling system is contaminated, flush the cooling system as follows:

1. Drain the coolant from the engine.
2. Refill with soft clean water.

NOTE:
If the engine is hot, fill slowly to prevent rapid cooling and distortion of the engine castings.

3. Start the engine and operate it for 15 minutes after the thermostats have opened to thoroughly circulate the water.
4. Drain the unit completely.
5. Refill with clean water and operate for 15 minutes after the thermostats have opened.
6. Drain the unit completely.
7. Fill with 50/50 antifreeze/water and precharge of inhibitor.
8. Purge entrapped air by allowing the engine to warm–up without the pressure cap installed. With the transmission in neutral, increase engine speed above 1000 r/min. Add coolant as required.
9. Allow engine to cool.
10. Install the pressure cap after filling the coolant level to the bottom of the radiator filler neck.

13.5.5 Turbocharger

Inspect the mountings, intake and exhaust ducting and connections for leaks. Check the oil inlet and outlet lines for leaks and restrictions to oil flow. Check for unusual noise or vibration and, if excessive, remove the turbocharger and correct the cause. Refer to section 6.4.1.

13.5.6 Battery

On batteries equipped with charge indicator eyes, periodically check for adequate charge. If batteries are the filler cap type, check the level of the electrolyte every 100 hours or every 7,500 miles (12,000 km). In warm weather, however, it should be checked more frequently due to a more rapid loss of water from the electrolyte. Electrolyte should be maintained in accordance with the battery manufacturer's recommendations. Periodically remove, check and clean battery post terminals and connections. Replace corroded or damaged parts. Refer to section 8.3.1.

13.5.7 Drive Belts

New standard vee–belts will stretch after the first few hours of operation. Run the engine for 10 to 15 minutes at 1200 r/min to seat the belts, then readjust the tension. Check the belts and tighten the fan drive, battery charging generator or alternator and other accessory drive belts after 1/2 hour or 15 miles and again after 8 hours or 250 miles (402 km) of operation. Thereafter, check the tension of the drive belts every 100 hours or 7,500 miles (12,000 km) and adjust, if necessary. Belts should be neither too tight nor too loose. Belts that are too tight impose excess loads on the crankshaft, fan and/or alternator bearings, shortening both belt and bearing life. Excessively overtightened belts can result in crankshaft breakage. A loose belt will slip and may cause damage to accessory components.

NOTE:
Replace ALL belts in a set when one is worn.

Single belts of similar size should not be used as a substitute for a matched belt set: premature belt wear can result because of belt length variation. All belts in a matched belt set are within .032 in. (0.81 mm) of their specified center distances.

With a belt tension gage, J 41251, or equivalent, adjust the belt tension as listed in Table 13–1.

Fan Drive Single Belt	Fan Drive 2 or 3 Belts	New Alternator Belts 2 1/2 in.	Used Alternator Belts 2 1/2 in.
80–100 lb (355 – 455 N)	60–80 lb (266 – 355 N)	125 lb (556 N)	100 lb (445 N)

Table 13–1 Belt Tensions

If a belt tension gage is not available, adjust the belt tension so that a firm push with the thumb, at a point midway between the two pulleys, will depress the belt 12.70–19.05 mm (.500 in.–.750 in.).

NOTE:
When installing or adjusting an accessory drive belt, be sure the bolt at the accessory adjusting pivot point is properly tightened, as well as the bolt in the adjusting slot.

NOTE:
Drive belts (vee and poly–vee) should be replaced every 2,000 hours or 100,000 miles (160,000 km).

Twelve rib poly–vee belts are used with the 50 DN Alternator. The 50 DN alternator drive belt tension is set at 300 lb (1335 N) during engine assembly and belt replacement using Kent Moore belt tension gauge, J 41050, or equivalent. A new belt loses tension rapidly during the first few minutes of operation. Therefore, it is important to check the tension after 10 to 15 minutes of operation. Allow the belt to cool with the engine off for 10 to 15 minutes before measuring tension.

- ❑ If the tension on the belt is greater than or equal to 200 lb (890 N), no retensioning is required.
- ❑ If the tension on the belt is less than 200 lb (890 N), retention the belt to 200 lb (890 N)

Periodic retensioning on the belt is required to maximize belt life. The belt tension should be measured once per month or every 10,000 miles (16000 km), whichever comes first.

A belt tensioning tool is available from Detroit Diesel, J 39966. This is a Borroughs belt tension gauge. The gauge is calibrated from 175 to 350 lb (779 to 1558 N) The following procedure will describe proper use of the belt tensioning tool:

1. Poly–vee belts are very sensitive to undertension. Without a gauge and proper tension measurement, the belt tension will probable be too low. Undertension wears belts rapidly and will lead to premature belt failure.
2. Measure the belt tension between the alternator drive pulley and the upper idler pulley, or between the upper idler pulley and the alternator pulley.

NOTICE:
Do not let gauge handle snap back after pressing handle when not installed on belt under tension. Broken gear will result.

3. Fully press the plunger on the belt gauge. The belt must pass between the hook and the leg pads. The entire belt width must be supported by the hook and leg pads.
4. Use quick release on the gauge handle. Read tension on the face of the gauge. Repeat the measurement 2 or 3 times to ensure accuracy.
5. The support legs on the gauge should not contact pulleys or any other engine hardware.
6. Keep gauge clean. Dirt will wear out the leg pads.

13.5.7.1 Inspect for Rib Cracking

As a poly–vee belt goes through its natural life, it passes through several phases:

- ❑ After an extended time in service, minor rib cracks may appear, usually one or two cracks per inch of belt. See Figure 13–3. This condition is considered normal.

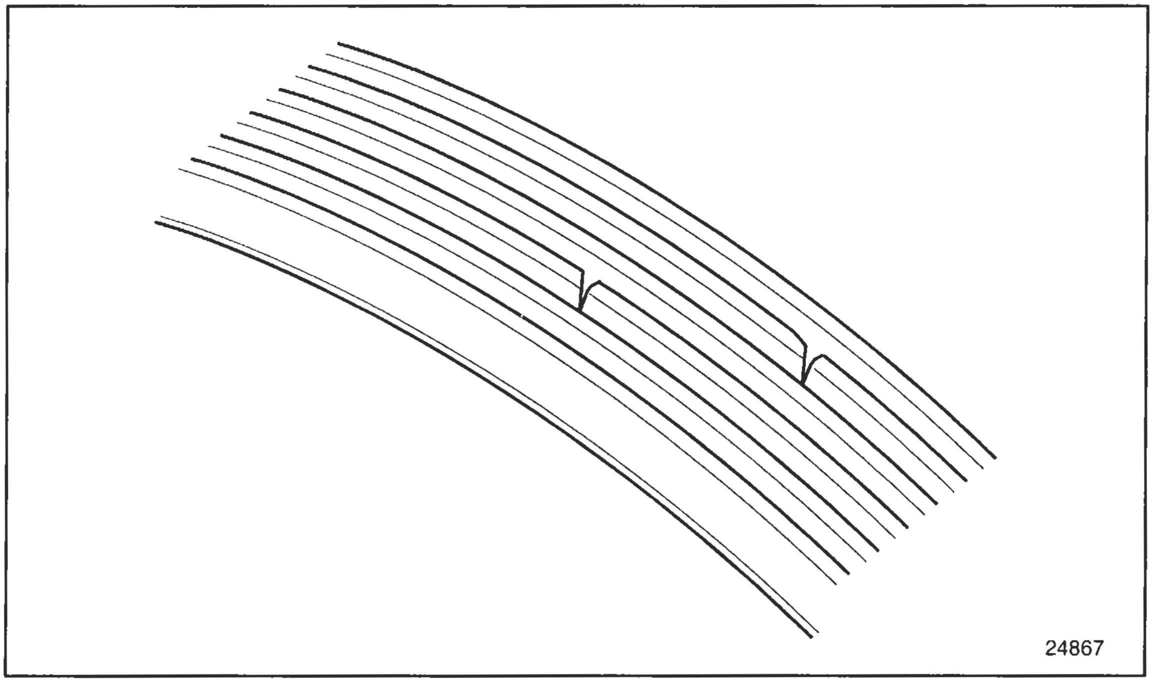


Figure 13–3 Minor Rib Cracking

- ❑ A replacement concern occurs when the belt ribs exhibit severe multiple cracking (see Figure 13–4). This leads to "chunking" (breaking away of rib material). see Figure 13–5

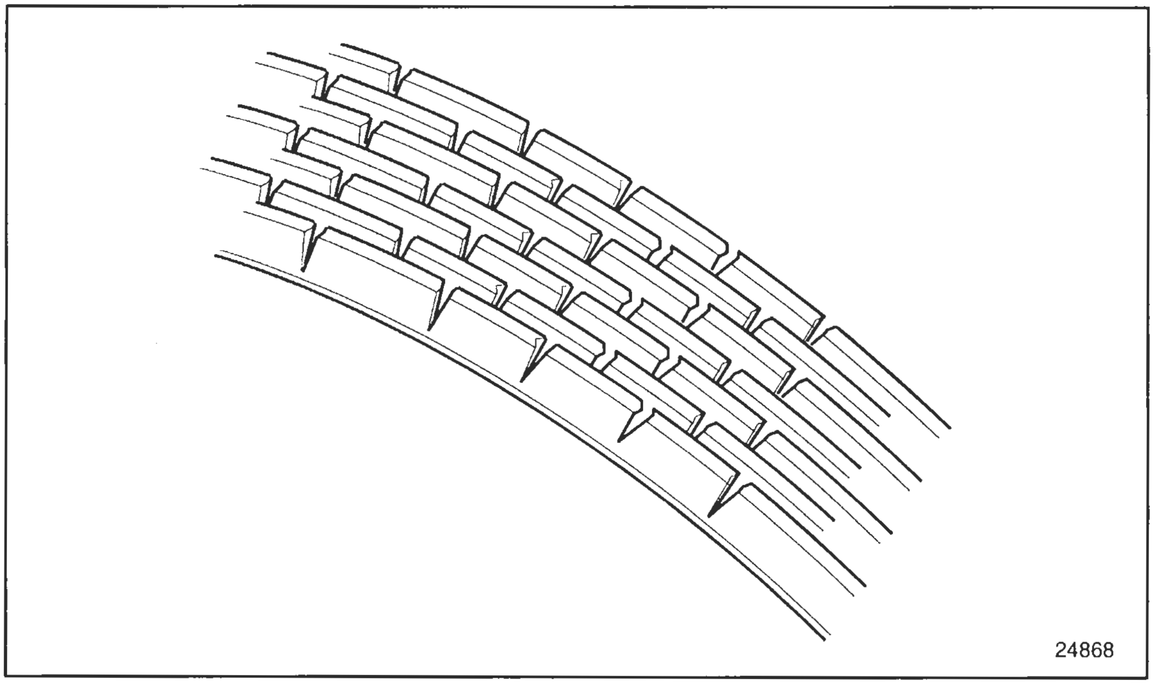


Figure 13–4 Severe Rib Cracking

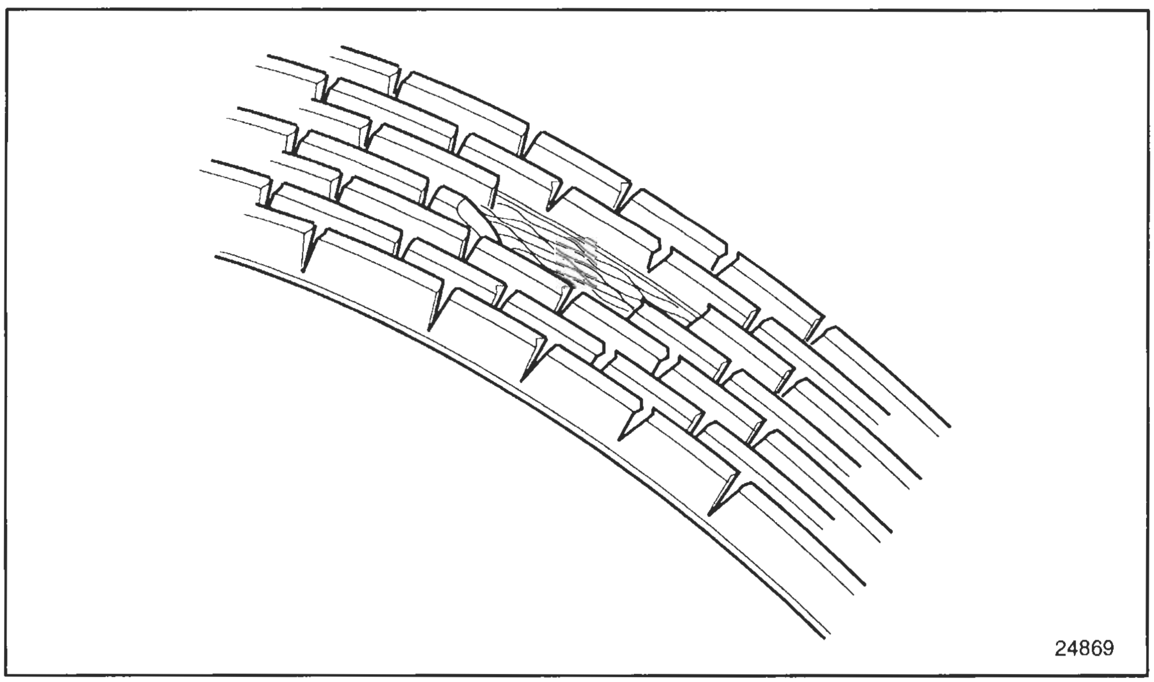


Figure 13–5 Rib Chunking

- ❑ When severe cracking or rib "chunking" appears, belt replacement is required.

13.5.7.2 Inspect for Rib Sidewall Glazing

When the ribs appear to have a shiny surface that is hard and brittle, it is usually a symptom of belt slippage. This results from inadequate tension, extreme temperature, or both. Both characteristics will lead to severe cracking and failure, often with little advance warning. If this happens, locate the cause and correct before installing a new belt.

13.5.7.3 Inspect for Belt Wear

Accelerated wear on any part of the belt fabric backing, tensile cord, or rib rubber is a concern and should be investigated. The causes of accelerated wear are:

- ❑ Drive misalignment – For efficient belt performance, misalignment must not exceed 1.59 mm (1/16 in.) for each 305 mm (12.0 in.) of belt span
- ❑ Incorrect belt length
- ❑ Environmental conditions – Temperature, excessive exposure to engine fluids, etc.
- ❑ Abrasive material – Stones, sand, metal shavings, etc.

13.5.7.4 Inspect for Foreign Objects

Premature failure may be caused by the belt coming in contact with a foreign object.

NOTICE:
Any object protruding into the path of the belt drive that contacts the belt will cause damage and failure of the belt.

Prior to installing a new belt, verify removal of any foreign objects protruding into the belt path.

13.5.7.5 Inspect for Noise Vibration

Much effort has gone into the design of each poly–vee belt drive in order to prevent noise vibration. However, field problems occasionally occur. Some causes of noise vibration are:

- ❑ Misalignment – This may cause a chirping noise, especially at or near idle speed.
- ❑ Mounting – Rigid bracketing of accessories is a must for acceptable free belt span vibration.

NOTE:
Some span vibration is to be expected during the range of engine speed and accessory loading.

- ❑ Belt tension – Insufficient belt tension may cause a high – pitched howl (squeal) or rasping sound during engine acceleration or deceleration.

13.5.8 Air Compressor

Remove and clean all air compressor air intake parts every 150 hours or 15,000 miles (24,000 km). Refer to section 10.1.2. To clean either the hair–or polyurethane–type compressor air strainer element, saturate and squeeze it in fuel oil, or any other cleaning agent that would not be detrimental to the element, until it is dirt–free. Then, dip the element in lubricating oil and squeeze it dry before placing it back in the air strainer.

For replacement of the air strainer element, contact the nearest servicing dealer; replace with the polyurethane element, if available.

Every 12 months or 30,000 miles (48,000 km)[300 hours for industrial applications] tighten the air compressor mounting bolts.

13.5.9 Air Cleaner

Inspect the air cleaner element every 15,000 miles (24,000 km) for vehicle engines, 150 hours for non–vehicle engines, or more often if the engine is operated under severe dust conditions. Replace the element if necessary. Check the gaskets for deterioration and replace, if necessary. If the dry type air cleaner is equipped with an aspirator, check for aspirator damage or clogging. Clean and repair as necessary.

Under no engine operating conditions should the air inlet restriction exceed 20 inches of water (5.0 kPa). A clogged air cleaner element will cause excessive intake restriction and a reduced air supply to the engine.

Dry–type air cleaner elements used in on–highway applications should be discarded and replaced with new elements when the maximum allowable air inlet restriction has been reached. No attempt should be made to clean or reuse on–highway elements after these intervals.

Dry–type elements used in industrial applications should be discarded and replaced with new elements after one year of service or when the maximum allowable air intake restriction has been reached, whichever comes first. In cases where the air cleaner manufacturer recommends cleaning or washing elements, the maximum service life is still one year or maximum restriction. Cleaning, washing and inspection must be done per the manufacturer's recommendations. Inspection and replacement of the cover gaskets must also be done per the manufacturer's recommendations.

13.5.10 Lubricating Oil Filter

Install new full flow spin–on oil filters at a **maximum** of 15,000 miles (24,000 km) (truck engines) 6,000 miles (10,000 km) (coach engines) or 150 hours (non–vehicle engines) or each time the engine oil is changed, whichever comes first. Install the new filters, turning them until they contact the gasket fully with no side movement, then turn an additional 2/3 turn by hand.

Make a visual inspection of all lubricating oil lines for wear and/or chafing. If any indication of wear is evident, replace the oil lines and correct the cause.

If the engine has not been operated for a prolonged period or the turbocharger has been removed or replaced, prelubricate the turbocharger as outlined under "Assembly of Turbocharger." Refer to section 6.4.4.

Check for oil leaks after starting the engine.

13.5.11 Fuel Filters

Install new fuel filters every six months or 15,000 miles (24,000 km) (truck engines) 6,000 miles (10,000 km) (coach engines) or 150 hours (non–vehicle engines) or when plugging is indicated.

A method of determining when filters are plugged to the extent that they should be changed is based on the fuel pressure at the cylinder head fuel inlet fitting and the inlet restriction at the fuel pump. In a clean system, the maximum pump inlet restriction should not exceed 20.3 kPa (6 in. Hg) and must not exceed 12 in. Hg (41 kPa) with a dirty system.

At normal operating speeds and with the standard .080 in. (2.03 mm) restriction fittings, the fuel pressure at the cylinder head inlet is 345–577 kPa (50–75 lb/in.^{2}). Change the fuel filters whenever the inlet restriction at the fuel pump reaches 41 kPa (12 in. Hg) at normal operating speeds and whenever the fuel pressure at the cylinder head inlet fitting falls to the minimum fuel pressure shown above.

Spin–on type primary and secondary fuel filters are used on Series 50 engines. The spin–on type consists of a shell, element, and gasket unitized into the single cartridge and a filter cover, which includes a threaded sleeve to accept the spin–on filter cartridge. An optional fuel/water separator may be installed in place of the standard primary filter.

Replace spin–on type primary or secondary filter elements as follows:

1. With the engine shut down, place a suitable container under the filter.
2. A fuel shutoff valve may be installed on the discharge side of the secondary fuel filter. If installed, turn the handle on the shutoff valve to the **closed** position (perpendicular to the valve).
3. Using a suitable band type filter wrench, remove the primary and secondary fuel filters. Dispose of the filters in an environmentally responsible manner, according to state and federal (EPA) recommendations.

4. Fill new replacement filters with clean fuel oil, and coat the gaskets lightly with clean fuel oil.

NOTICE:
Overtightening may crack or distort the adaptors.

5. Thread the new filters onto the adaptors until they make full contact with the gasket and no side movement is evident. Then rotate an additional one-half turn **by hand**.
6. Turn the handle on the shutoff valve (if installed) to the **open** position (in line with the valve).

NOTICE:
To improve engine starting, have replacement filters filled with fuel and ready to install immediately after used filters are removed. This will prevent possible siphoning and fuel system aeration.

7. Start the engine, and check for leaks.

NOTICE:
Under no circumstances should the starting motor and fuel pump be used to prime the fuel filters. Prolonged use of the starting motor and fuel pump to prime the fuel system can result in damage to the starter, fuel pump, and injectors and cause erratic running of the engine because of air in the lines and filters.

[a] If the engine fails to start after filter replacement, the fuel system will require priming with tool J 5956 (or equivalent). Authorized Detroit Diesel service outlets are properly equipped to perform this service.

Replace fuel/water separator as follows:

1. Drain off some fuel by opening the drain valve.
2. Using a strap wrench, remove the element and bowl together. Remove the bowl from the element. The filter and bowl have standard right-hand threads, so turn counterclockwise to remove.
3. Clean the bowl and the O-ring seal.

NOTICE:
To avoid damaging the bowl or the filter, do not use tools when tightening.

4. Apply a light coating of clean fuel or grease to the O-ring seal, spin the bowl onto the new filter, and *tighten by hand*.
5. Apply a light coating of clean fuel or grease to the new O-ring seal on the top of the filter. Spin the filter and bowl assembly onto the filter head, and *tighten by hand* until snug.
6. To eliminate air from the filter, operate the primer pump on the filter head (if equipped) until the fuel purges at the filter assembly.
7. Start the engine, and check for leaks. Correct any leaks with the engine off.

13.5.12 Coolant Filter and Water Pump

Inspect the water pump drain hole every 6 months making sure it is open. A small chemical build up or streaking at the drain hole may occur, and this is not an indication of a defective water pump or seal. If coolant does not leak from the drain hole under normal operating conditions, do not replace the water pump. If the cooling system is protected by a coolant filter and conditioner, the element should be changed every 15,000 miles (24,000 km) or 150 hours (industrial applications). Use the proper coolant filter element in accordance with instructions given under coolant specifications. Refer to section 5.3.

13.5.13 Cranking Motor

Refer to OEM maintenance guidelines.

13.5.14 Air System

It is important with turbocharged engines that all the connections in the air system be checked to be sure they are tight. Check all hoses and ducting for punctures, deterioration or other damage and replace, if necessary.

Refer to OEM maintenance guidelines.

13.5.15 Exhaust System

Check the exhaust manifold retaining bolts and other connections for tightness. Check for proper operation of the exhaust pipe rain cap, if so equipped.

Refer to OEM maintenance guidelines.

13.5.16 Engine (Steam Clean)

Refer to OEM maintenance guidelines.

NOTICE:
Do not apply steam or solvent directly on the battery charging generator/alternator, starting motor, DDEC components, sensors, or other electrical components, as damage to electrical equipment may result.

Steam clean the engine and engine compartment.

13.5.17 Radiator

Inspect the exterior of the radiator core every 12 months or 30,000 miles–48,000 km (300 hours for industrial applications) and, if necessary, clean it with a quality grease solvent, such as mineral spirits, and dry it with compressed air. **Do NOT use fuel oil, kerosene or gasoline.** It may be necessary to clean the radiator more frequently if the engine is being operated in extremely dusty or dirty areas.

Refer to OEM maintenance guidelines.

13.5.18 Oil Pressure

Under normal operation, oil pressure is noted each time the engine is started. In the event the equipment is equipped with warning lights rather than pressure indicators, the pressure should be checked and recorded every 60,000 miles (96,000 km) for vehicle engines or 600 hours for stationary or industrial engines.

Refer to OEM maintenance guidelines.

13.5.19 Battery Charging Alternator

Inspect the terminals for corrosion and loose connections and the wiring for frayed insulation.

Refer to OEM maintenance guidelines.

13.5.20 Engine and Transmission Mounts

Check the engine and transmission mounting bolts and the condition of the mounting pads every 600 hours or 60,000 miles (96,000 km). Tighten or repair as necessary.

Refer to OEM maintenance guidelines.

13.5.21 Crankcase Pressure

Check and record the crankcase pressure every 600 hours–96,000 km (60,000 miles). Refer to section 58.3 in 6SE494 *Series 50 Troubleshooting Manual*.

13.5.22 Fan Hub

If the fan bearing hub assembly has a grease fitting, use a hand grease gun and lubricate the bearings with two shots of Texaco Premium RB grease, or Mobilgrease HP, or an equivalent lithium–base multi–purpose premium grease at the following intervals as listed in Table 13–2. Care should be taken not to overfill the housing.

Engine Application	Fan Bearing Lubrication Interval
On–highway Truck Engine	15,000 miles (24,000 km)
Transit Coach Engine	6,000 miles (9,600 km)
Non–vehicle Engine	1,050 Hours

Table 13–2 Fan Bearing Lubrication Intervals

NOTICE:

Failure to properly lubricate the fan hub bearing at required intervals my result in fan bearing, spindle damage or both. This could lead to fan malfunction, loosening or both, which could result in serious engine damage.

NOTE:
This is a change from the original recommendation, which required greasing the bearing on vehicle engines every 100,000 miles (160,000 km).

13.5.23 Thermostats and Seals

Inspect the thermostats and seals every 24 months. Refer to section 4.3.2.1 for thermostat inspection procedures. The thermostats and seals should be replaced every 200,000 miles (240,000 km) for vehicle engines or 4,000 hours for non–vehicle engines.

13.5.24 Crankcase Breather

Remove the internally mounted (in the engine rocker cover) crankcase breather assembly annually (vehicle engines) or every 1,050 hours (non–vehicle engines) and wash the steel mesh pad in clean fuel oil. Refer to section 1.6.2. This cleaning period may be reduced or lengthened according to the severity of service.

13.5.25 Engine Tune–up

There isn't a scheduled interval for performing an engine tune–up. As long as the engine performance is satisfactory, no tune–up should be needed. A check of the intake and exhaust valve clearances, and injector heights, refer to section 12.2, every 6,000 miles (9,600 km) for vehicle engines or 1,500 hours for non–vehicle engines, is all that is recommended. Once the initial measurement/adjustments have been made, no tune–up should be needed as long as the engine performance is satisfactory.

13.A ADDITIONAL INFORMATION

Description **Page**

SERVICE TOOLS

Listed in Table 13–3 are the service tools used in this section.

Tool Number	Tool Name
J 24460–01	Cooling System Pressure Tester Kit
J 29917	Oil Filter Wrench
J 39966	Belt Tension Gage
J 41050	Belt Tension Gage
J 41251	Belt Tension Gage
J 5956	Fuel System Primer

Table 13–3 Tools Used in the Maintenance Section

14 ENGINE STORAGE

14.1 PREPARING ENGINE FOR STORAGE

When an engine is to be stored or removed from operation for a period of time, special precautions should be taken to protect the interior and exterior of the engine, transmission and other parts from rust accumulation and corrosion. The parts requiring attention and the recommended preparations are given below:

- ❑ It will be necessary to remove all rust or corrosion completely from any exposed part before applying rust preventive compound. Therefore, it is recommended that the engine be processed for storage as soon as possible after removal from operation.
- ❑ The engine should be stored in a building that is dry and can be heated during the winter months. Moisture absorbing chemicals are available commercially for use when excessive dampness prevails in the storage area.

14.1.1 Temporary Storage (30 Days or Less)

To protect an engine for a temporary period of 30 days or less, proceed as follows:

1. Drain the engine crankcase. Refer to section 13.5.1.
2. Fill the crankcase to the proper level with the recommended viscosity and grade of oil listed in Table 14-2.
3. Fill the fuel tank with the recommended grade of fuel oil listed in Table 14-3. Operate the engine for two minutes at 1200 r/min and no load.

NOTE:
Do not drain the fuel system or the crankcase after this run.

4. Check the air cleaner and service it, if necessary. Refer to OEM guidelines.
5. If freezing weather is expected during the temporary storage period, add an ethylene glycol base antifreeze solution to the cooling system in accordance with the manufacturer's recommendations. Otherwise, the coolant system should be flushed and filled with a good rust inhibitor to prevent rusting of the outside diameter of the cylinder liners. Refer to section 13.5.4.
6. Remove electrical components. Refer to section 8.
7. Clean the engine exterior of the engine (except electrical components) with fuel oil.
8. Seal all of the engine openings with a material used for this purpose. The material used for sealing must be waterproof, vapor proof and possess sufficient physical strength to resist puncture and damage from the expansion of entrapped air.

14.1.2 RESTORING A TEMPORARILY STORED ENGINE

An engine that was stored in accordance with the guidelines for temporary storage (refer to section 14.1.1.) can be returned to service in a short time by removing the seals at the engine openings and by checking the engine coolant, fuel oil, lubricating oil and transmission oil levels.

14.1.3 Extended Storage (More Than 30 Days)

To prepare an engine for extended storage (more than 30 days), follow this procedure:

1. Drain the cooling system. Refer to section 13.5.4.
2. Flush with clean, soft water. Refer to section 13.5.4.
3. Refill with clean, soft water and add a rust inhibitor to the cooling system. Refer to section 5.3.
4. Circulate the coolant by operating the engine until normal operating temperature is reached, listed in Table 14–1.

Cooling System Parameters	Normal Range for 2100 r/min Operation	Normal Range for 1800 r/min Operation
Coolant temperature normal – °C (°F)	88 (190)	88 (190)
Coolant inlet restriction, maximum–kPa (in. Hg)	0.0 (0.0)	0.0 (0.0)
Engine coolant capacity–liters (quarts)	23 (24)	23 (24)
Minimum pressure cap–kPa (lb/in.^{2})	48.3 (7)	48.3 (7)
Maximum top tank temperature–°C (°F)	99 (210)	99 (210)
Minimum top tank temperature–°C (°F)	71 (160)	71 (160)
Thermostats start to open–°C (°F)	88 (190)	88 (190)
Thermostats are fully open–°C (°F)	96 (205)	96 (205)

Table 14–1 Series 50 Operating Conditions

5. Stop the engine.
6. Remove the drain plug to drain the engine crankcase. Refer to section 13.5.1.
7. Install and tighten the 3/4 in.–14 square, magnetic oil drain plug to 45–56 N·m (33–41 lb·ft) torque.
8. Install new lubricating oil filters. Refer to section 13.5.11.
9. Fill the crankcase to the proper level with a 30–weight preservative lubricating oil MIL–L–21260C, Grade 2. Refer to section 13.5.1.
10. Drain the fuel tank. Refer to section 13.5.2.
11. Refill with enough clean No. 1 diesel fuel or pure kerosene to permit the engine to operate for about ten minutes. If it isn't convenient to drain the fuel tank, use a separate, portable supply of recommended fuel.

NOTE:
If engines in vehicles are stored where condensation of water in the fuel tank may be a problem, add pure, waterless isopropyl alcohol (isopropanol) to the fuel at a ratio of one pint to 125 gallons of fuel, or 0.10% by volume. Where biological contamination of fuel may be a problem, add a biocide such as Biobor JF (or equivalent) to the fuel. When using a biocide, follow the manufacturer's concentration recommendations, and observe all cautions and warnings.

12. Drain the fuel system. Refer to section 13.5.2.
13. Remove the fuel filters. Refer to section 2.6.1.
14. Discard the used filters.
15. Fill new filters with No. 1 diesel fuel or pure kerosene.
16. Install new oil filters on the engine. Refer to section 1.
17. Operate the engine for five minutes to circulate the clean fuel oil throughout the engine. Be sure the engine fuel system is full.
18. Disconnect the fuel return line and the inlet line at the primary filter and securely plug both to retain the fuel in the engine. Refer to section 13.5.3.
19. Service the air cleaner. Refer to section 13.5.10.
20. To prepare the transmission, power take-off and turbocharger:
    [a] Follow the manufacturer's recommendations for prolonged storage to store the transmission.
    [b] Follow the manufacturer's recommendations for prolonged storage to store the power take-off.
    [c] Since turbocharger bearings are pressure lubricated through the external oil line leading from the oil filter adaptor while the engine is operating, no further attention is required. However, the turbocharger air inlet and turbine outlet connections should be sealed off with moisture resistant tape.

NOTICE:
Do not apply oil, grease or any wax base compound to the flywheel. The cast iron will absorb these substances, which can sweat out during operation and cause the clutch to slip.

21. Apply a non-friction rust preventive compound to all exposed engine parts. If convenient, apply the rust preventive compound to the engine flywheel. If not, disengage the clutch mechanism to prevent the clutch disc from sticking to the flywheel.
22. Drain the engine cooling system. Refer to section 13.5.4.
23. Drain the preservative oil from the engine crankcase. Reinstall and tighten the 3/4 in.–14 square, magnetic drain plug to 45–56 N·m (33–41 lb·ft) torque.
24. Remove and clean the battery and battery cables with a baking soda–water solution and rinse with fresh water. Do not allow the soda solution to enter the battery.
25. Add distilled water to the electrolyte (if necessary) and fully charge the battery.

NOTICE:
Never store a battery in a place below 0°C (32°F).

26. Store the battery in a cool, dry place. Keep the battery fully charged and check the level and specific gravity of the electrolyte regularly.
27. Insert heavy paper strips between the pulleys and drive belts to prevent sticking.
28. Seal all engine openings including the exhaust outlet, with moisture resistant tape. Use cardboard, plywood or metal covers where practical.
29. Clean and dry the exterior painted surfaces of the engine and spray with a suitable liquid automobile body wax, a synthetic resin varnish or a rust preventive compound.
30. Protect the engine with a good weather–resistant tarpaulin and store it under cover, preferably in a dry building which can be heated during the winter months.

NOTE:
Plastic may be used for indoor storage.

14.1.4 Outdoor Storage (30 Days or Less)

In some cases outdoor storage may be unavoidable.

NOTE:
Outdoor storage of engines is not recommended.

If units must be kept out–of–doors. Refer to section 14.1.3.

NOTICE:
Do NOT use plastic sheeting for outdoor storage. Plastic is fine for indoor storage. When used outdoors, however, enough moisture can condense on the inside of the plastic to rust ferrous metal surfaces and pit aluminum surfaces. If a unit is stored outside for any extended period of time, severe corrosion damage can result.

Protect units with quality, weather–resistant tarpaulins (or other suitable covers) arranged to provide for air circulation.

The stored engine should be inspected periodically. If there are any indications of rust or corrosion, corrective steps must be taken to prevent damage to the engine parts.

14.1.5 Outdoor Storage (More Than 30 Days)

In some cases outdoor storage may be unavoidable.

NOTE:
Outdoor storage of engines is not recommended.

If units must be kept out–of–doors. Refer to section 14.1.3.

NOTICE:
Do NOT use plastic sheeting for outdoor storage. Plastic is fine for indoor storage. When used outdoors, however, enough moisture can condense on the inside of the plastic to rust ferrous metal surfaces and pit aluminum surfaces. If a unit is stored outside for any extended period of time, severe corrosion damage can result.

Protect units with quality, weather–resistant tarpaulins (or other suitable covers) arranged to provide for air circulation.

The stored engine should be inspected periodically. If there are any indications of rust or corrosion, corrective steps must be taken to prevent damage to the engine parts. Perform a complete inspection at the end of one year and apply additional treatment as required.

14.2 RESTORING AN EXTENDED STORAGE ENGINE

Use the following procedure to restore an engine that has been in extended storage.

1. Remove the covers and tape from all of the openings of the engine, fuel tank and electrical equipment. Do not overlook the exhaust outlet.
2. Remove the plugs from the inlet and outlet fuel lines and connect the lines to their proper position.
3. Wash the exterior of the engine with fuel oil to remove the rust preventive. (Do NOT wash electrical components.)
4. Remove the rust preventive from the flywheel.
5. Remove the paper strips from between the pulleys and drive belts.
6. Fill the crankcase to the proper level, with the recommended grade of lubricating oil listed in Table 14-2. Use a pressure lubricator to insure all bearings and rocker shafts are oiled.

Specification	Recommendation
SAE Viscosity Grade	15W–40
API Classification	CG–4
Military Specification	MIL–L–2104E
HT/HS Viscosity	3.7 cP (minimum)

Table 14–2 Recommended Engine Oil

7. Fill the fuel tank with one of the fuels listed in Table 14-3.

General Fuel Classification	ASTM Test	No. 1 ASTM 1–D	No. 2 ASTM 2–D
Gravity, °API (Not Specified in ASTM D 975)	D 287	40–44	33–37
Flash Point, Minimum–°F (°C)	D 93	100 (38)	125 (52)
Viscosity, Kinematic–cSt @ 100°F (40°C)	D 445	1.3–2.4	1.9–4.1
Cloud Point (Not Specified in ASTM D 975)	D 2500	See Note	See Note
Sulfur Content, Maximum–wt%	D 129	0.05* (0.5†)	0.05* (0.5†)
Carbon Residue on 10%, Maximum–wt%,	D 524	0.15	0.35
Accelerated Stability, Total Insolubles, Maximum–mg/100 mL	D 2274	1.5	1.5
Ash, Maximum–wt %	D 482	0.01	0.01
Cetane Number, Minimum (Differs from ASTM D 975)	D 613	45	45
Distillation Temperature, °F (°C)	ASTM Test	No. 1 ASTM 1–D	No. 2 ASTM 2–D
IBP, Typical (Not Specified in ASTM D 975)	D 86	350 (177)	375 (191)
10% Typical (Not Specified in ASTM D 975)	D 86	385 (196)	430 (221)
50% Typical (Not Specified in ASTM D 975)	D 86	425 (218)	510 (256)
90% Maximum (Differs from ASTM D 975)	D 86	500 (260)	625 (329)
End Point, Maximum (Not Specified in ASTM D 975)	D 86	550 (288)	675 (357)
Water & Sediment, Maximum wt%	D 1796	0.05	0.05

* U.S. on–highway requirement

† Nondramatic and off–highway applications only

Note: The cloud point should be 10°F (6°C) below the lowest expected fuel temperature to prevent clogging of fuel filters by crystals.

Table 14–3 Fuel Oil Selection Chart

8. Close all of the drain cocks and fill the engine cooling system with clean soft water and proper inhibitors. Refer to section 13.5.4. If the engine is to be exposed to freezing temperatures, fill the cooling system with an ethylene glycol base antifreeze solution. Refer to section 5.3.1.1.

9. Install and connect the battery. Ensure that the average specific gravity of the battery is 1.265 or higher. Refer to section 11.1.8. Charge the battery if necessary.

10. Perform the following:
    - [a] Keep the air cleaner housing tight on the air intake pipe.
    - [b] Be sure the correct filter replacement is used.
    - [c] Keep the air cleaner properly assembled so the joints are strictly air tight.
    - [d] Repair any damage to the air cleaner or related parts immediately.
    - [e] Inspect and clean or replace the air cleaner elements as operating conditions warrant.
    - [f] Carefully inspect the entire system periodically. Enough dust-laden air will pass through an almost invisible crack or opening to eventually cause damage to an engine.
    - [g] If a foam or fabric air cleaner element soaked with sticky dirt-holding substance was previously installed, check for the presence of coated engine components. Remove and clean them with a suitable solvent, as required, and blow dry with compressed air.

CAUTION:

To avoid personal injury when blow drying, wear adequate eye protection and do not exceed 276 kPa (40 lb/in.^{2}) air pressure.

11. Follow the manufacturer's recommendations covering the return of the transmission to service.
12. Follow the manufacturer's recommendations covering the return of the power take-off to service.
13. Remove the covers from the turbocharger air inlet and turbine outlet connections. Prelube the turbocharger. Refer to section 6.4.5.
14. After all of the preparations have been completed, start the engine. The small amount of rust preventive compound which remains in the fuel system will cause smoky exhaust for a few minutes.

NOTE:
Before subjecting the engine to a load or high speed, it is advisable to allow the engine to reach normal operating temperature. Then, monitor the DDEC Diagnostic Data Link for trouble codes. Refer to section 15 of the *Series 50 Troubleshooting Manual*, entitled "Basic Knowledge Required For Using Electrical Troubleshooting."

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